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ARRANGEMENT OF ELECTROLYTIC LABORATORIES

WITH SPECIAL REFERENCE TO THE REQUIREMENTS OF METALLURGICAL PRACTICE

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MONOGRAPHS

—ON—

APPLIED ELECTROCHEMISTRY

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MONOGRAPHS OF APPLIED ELECTROCHEMISTRY.

VOL. IV.

ARRANGEMENT OF

ELECTROLYTIC LABORATORIES

WITH SPECIAL REFERENCE TO THE
REQUIREMENTS OF

METALLURGICAL PRACTICE

BY

H. NISSENSON

DIRECTOR OF THE CENTRAL LABORATORY OF THE
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Translator's Preface.

The rapid increase in interest in electrochemistry in England and America during the last few years, and especially the rapidly increasing importance of applied electrochemistry, is giving rise to the need of more laboratories suitably arranged and properly equipped for studying electrochemical problems.

The best guide for the erection of such laboratories is undoubtedly to study existing electrochemical laboratories, in order to profit by the experience of pioneers in this work. The thirteen laboratories described by Herr Nissenson are fairly representative of European arrangements, while those added by the translator,—that of the University of Wisconsin, by Professor C. F. Burgess, and that of the Massachusetts Institute of Technology, by Professor H. M. Goodwin, and that of Lehigh University—will give a view of the arrangements found suitable in America. As thus constituted, the book ought to prove useful to anyone wishing to furnish an electrochemical laboratory for almost any electrochemical purpose.

The translator wishes to thank Professor Burgess and Goodwin for permission to include their articles, also the publishers of Electrochemical Industry for the loan of the cuts to illustrate those articles, and further to thank Mr. Walter S. Landis, Instructor in the department of Metallurgy at Lehigh University for assistance in preparing the manuscript for the press.

Jos. W. Richards.

Lehigh University,
January, 1905.

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CONTENTS.

PAGE.

PART I.

1. Introduction 1
2. Purpose and Value of Electrolysis 1
3. Fundamental Ideas 3
4. Fundamental Laws of Electro-Technology 3
5. Calculation of Conductors 4
6. Components of an Electrolytic Equipment 5
 - (a) Source of the Current 5
 - (b) Measuring Instruments 6
 - (c) Current Regulators 7
 - (d) Conductors 8
 - (e) Switch-Boards 8
 - (f) Work Room 9
 - (g) Space Requirements 9

PART II.

DESCRIPTION AND EQUIPMENT OF ELECTROLYTIC LABORATORIES.

1. Aachen 11
2. Breslau 13
3. Clausthal 16
4. Darmstadt 18
5. Freiberg, Saxony 22
6. Giessen 22
7. Hoboken near Antwerp (Desilverizing Works) 24
8. Königsberg 29
9. Leoben 30
10. Central Laboratory of Dumont Brothers at Lüttich 32
11. Munich 35
12. University of Pennsylvania 37
13. Stolberg, Central Laboratory of the Stolberg Company 41

The Electrochemical Laboratory of the Massachusetts Institute of Technology. By Prof. H. M. Goodwin 51

Laboratory of Applied Electrochemistry, University of Wisconsin. By Prof. Charles F. Burgess 63

Lehigh Univeraity. By Prof. T. W. Richards 79

UNIVERSITY OF CALIFORNIA

PART I.

Introduction.

Although so much satisfactory material has been written upon the value and importance of analysis by electrolysis, yet it has not been appreciated, especially by our older colleagues, or they are not yet acquainted with this field. Our younger colleagues, who have had the good fortune to pursue their studies at a High School, equipped with a chair of electro-chemistry, have lacked on the one hand, the necessary experience to be able to judge of the value of electrolysis to analysis, and on the other hand, because they mostly have only learned one system of laboratory equipment for electrolysis, lack a general view of the various existing systems and methods, their advantages and disadvantages.

It seems to me therefore of the greatest importance to revert to this method of analysis, and to describe anew the advances which have been made and the experience gained.

I shall therefore in the present volume attempt to awaken further interest in electrolytic analysis, by explaining its value and purpose, offering a limited review of its present and possible scope and finally to describe in detail, that which appears to me the most suitable for metallurgical chemistry, upon the basis of eighteen years of practical experience. I beg the forbearance of my experienced colleagues for detailing here the fundamental laws and ideas, in a way the ABC of electricity, but it appears to me unavoidable for the complete attainment of the object of the work.

It is of importance that the business managers of mines, metallurgical plants, etc., should be able to follow the presentation and form an opinion of the matter, and they can then better appreciate the efforts of the chemist. On this account, I have endeavored to express myself in a way which will be generally understood.

Purpose and Value of Electrolysis.

The purpose of analytical electrolysis is the quantitative separation and estimation of the metals. It may be said that this pur-

pose is attainable by the older methods without the aid of the electric current, and that an equipment for electro-analysis is superfluous; that this opinion is incorrect I will show in what follows by a statement of the great advantages of electrolytic methods.

The great value of quantitative analysis by electrolysis for metallurgical chemistry as well as also for the application of the principles of chemical knowledge in practice, particularly for large industrial operations, lies in the fact that with this method of working the above purpose is attained more accurately, more surely and in a much shorter time.

In fact this last advantage of quantitative analysis by electrolysis cannot be mentioned too emphatically. The fact is well known that many estimations of metals, whose determination by the older methods required many hours, as the estimation of lead, copper, antimony, tin, cobalt and nickel in ores, the quantitative determination of alloys, metallurgical products, etc., are now performed by electrolysis in a few hours and with greater accuracy. The value of this method is still further increased by the fact that the chemist, during the real analysis, whose duration he knows exactly after several experiments, may quietly finish other work; that he may carry out a large number of electrolytic determinations at the same time, with a sufficiently large equipment; and that in certain tests he may by a single electrolysis simultaneously estimate two metals.

In large metallurgical operations, much depends on the obtaining of accurate results in the analysis of ores in the shortest time. It follows that those smelting works operate under the greatest advantage which learn earliest the approximate value of the ore content by means of the electroytic method, and in consequence of this can purchase by telegraph most advantageously in the desired quantity, before the ores are absorbed by another party.

It is also of the greatest importance to the smelter superintendent to have the laboratory furnish him exact results in the shortest possible time, that he may control and also correct in time the operation of the metallurgical process in question.

The value of quantitative analysis by electrolysis to the sciences follows from what has been said. It is well known that to-day all large institutions are furnished with more or less complete equip-

ments for analytical electrolysis; as Aachen, Breslau, Clausthal, Darmstadt, Giessen, Königsburg, Leoben, Munich, and many others.

Finally, electrolysis gives to the student the possibility of observing and judging his analysis uninterruptedly, learning to recognize and avoid errors and deficiencies, and enabling him to enter into practice with a certain self-confidence in this line of work, which to the same degree is impossible with the older methods.

Fundamental Ideas.

Before we go into a description of the equipment itself, we will, for the reasons stated in the introduction, put forward the following for an easier understanding of the subject.

The principal units of measurement in electricity are the *ampere,* the *volt* and the *ohm.*

The ampere is the unit of measurement for the mass or quantity of the current, abbreviated to I = intensity, and generally called "strength of current."

The volt is the unit for the measurement of the pressure which pushes the current through the conductor (either metal or fluid), abbreviated to E = electromotive force, and generally called "tension."

The ohm is the unit of measurement for the resistance which opposes the flow of the current through the conductor, abbreviated to W in German (Widerstand) or R in English (resistance).*

Fundamental Laws of Electro-Technology.

The fundamental law of electricity (we are here only concerned with direct currents, namely only those which always flow in the same direction) is Ohm's Law, which reads

$$E = I.R \qquad [V = A.\Omega]$$

or electromotive force (tension) = current strength × resistance, or, transposed

$$I = \frac{E}{R} \text{ or } R = \frac{E}{I} \qquad \left[A = \frac{V}{\Omega} \text{ or } \Omega = \frac{V}{A}\right]$$

* [These three quantities are more logically designated as A, V and O or Ω, the first letters of the units of measurement themselves.—*Translator.*]

The values and relations to each other of these electrical units may be conceived best by a comparison with steam. The current strength measured in "amperes" corresponds to the amount of steam made per second, measured in kilogrammes; the tension measured in "volts" corresponds to the steam pressure measured in atmospheres, and the resistance of the path of the current or the conductor, measured in "ohms" corresponds to the resistance which the steam has to overcome in its conductors, or the frictional resistance of the pipe walls.

If one with a steam pressure in a boiler (source of current) of say two atmospheres (analogous to volts) can force an amount of steam, say 20 kilogrammes (analogous to amperes) through a pipe say 10 centimetres effective diameter and of a certain length (analogous to resistance) in a unit of time, and then if—assuming the necessary boiler capacity—the amount of steam in the same time is to be doubled to 40 kilogrammes, the steam pressure must be raised to 4 atmospheres, or if this is not possible, then the area of the steam pipe must be doubled—one has a picture of the manner in which the corresponding electrical units are related to each other. If 20 amperes (kilogrammes per second) are passed through an electrolytic cell (conducting tube) with a total resistance of 0.1 ohm (frictional resistance) by a tension of the source of the current (boiler) of 2 volts (atmospheres), and it is desired to raise it to 40 amperes, then the tension must be raised to 4 volts or if that is not possible, the cross section (carrying space) must be doubled, in order to halve the resistance, it becoming 0.05 ohm.

Calculation of Conductors.

For calculating the necessary cross-section of the conductors this simple formula is used:

$$Q = \frac{L \cdot I \cdot 0.016}{V} \qquad \left[S = \frac{L \cdot A \cdot 0.016}{\Omega} \right]$$

where Q = the desired cross section of a copper conductor in square millimeters, L the total length of the same, the sum of the direct and return circuits, in meters, I the maxium intensity to be carried (current strength) in amperes, V = the maximum allowable tension loss in volts, and 0.016 the specific resistance of copper at 15° C.

Example: A conductor is required for an accumulator battery of four cells (= 8 volts) with a maximum discharge current of 40 amperes, the distance to the point of use being 15 meters, and the allowable voltage drop to be 5 per cent., or $0.05 \times 8 = 0.4$ volt. Calculate the required cross-section of the copper wire.

$$Q = \frac{2 \cdot 15 \cdot 40 \cdot 0.016}{0.4} = 48 \text{ sq. mm.}$$

Component of an Electrolytic Equipment.

Source of the Current.

In the equipment of an electrolytic laboratory, the most important element is a source of current, which has to have the capacity to furnish the required current to all the working places, for the longest time required and at a voltage as constant as possible. At the present time we have the following at our disposal:

1. Primary elements, namely those which in consequence of their composition have the power to furnish current by changing chemical into electrical energy.

For our purposes we need only concern ourselves with the Meidinger and the Bunsen cells. The first gives a very weak current so that even with a large battery only a slow precipitation of metals can be attained; its electromotive force is about 1.1 volts, and it has a somewhat high inner resistance. The latter gives a strong current at the beginning which after several hours drops off considerably; they are not constant enough and besides evolve injurious gases dangerous to health; their electromotive force is at first about 1.8 volts and the inner resistance is very small.

2. Thermo-piles, of which the Gülcher is the most highly recommended. This gives an electromotive force of 4 volts and has an inner resistance of 0.65 ohm, and they are therefore best used in practice in combination with accumulators, by the charging of which during the night, the output of the installation is considerably increased.

3. Accumulators or secondary elements, namely those which store up electrical energy furnished them, in the form of chemical work and which in discharging transform it again into electrical energy. Accumulators possess within their limits of capacity the advantage of great constancy, and with a sufficiently large electrode surface will give currents of any magnitude, and there-

fore should not be absent from any good electrolytic plant. That the battery may have long life it is essential to have it large enough. The electromotive force of a cell is about 2 volts, and the inner resistance is very small.

4. Dynamo machines, which can be obtained for any desired output of amperes and volts, but in reference to the constancy of their electromotive force are too dependent upon the constant speed of their driving agent, and during their operation always require a certain amount of attention, and therefore should be always combined with accumulators.

5. Connection with existing electrical lighting or power plants, of private or public ownership. In reference to the constancy of the electromotive force the same is true as was mentioned under 4, though possibly not to the same extent. The necessary accumulators can only be charged by central stations by the use of resistance, with the consequent loss of energy and expense, or in relation to the amount of current used almost without cost by connecting in series in one or more of the arc light circuits of proper current strength, and to prevent an overcharging of the batteries in case of the short circuit of one or more of the arc lights, it is necessary to interpose in the circuit an automatic circuit breaker, in addition to the safety devices present in each generating station. Finally motor-generators are suitable for charging accumulators, transforming high tension currents of small intensity into low tension high intensity currents. By the use of converters it is indifferent as to whether the main current from the central station is direct, or single or polyphase alternating. For these motor generators the same remarks apply as to the dynamo.

Measuring Instruments.

After the selection of the source of current, the choosing of suitable measuring instruments is of the greatest importance, because we can only hope for reliable results in electrolysis when these read correctly at all ordinary temperatures and over all points of their scale, in short are instruments of precision. So called commercial instruments are only applicable when they are frequently submitted to an exact calibration, which, however, is necessary from time to time even with instruments of precision.

Another fault of the technical electrical instruments is that their pointer does not come quickly enough to rest, while with instruments of precision the desired value can be read off almost immediately. Among the instruments of precision I mention here the aperiodic, cased instruments of perfect construction made by Hartmann & Braun and other firms. The large galvanometers, etc., are more precise and reliable, although leaving out of consideration their high price they are too susceptible to outside electrical and mechanical influences, and require for their safe handling a great amount of patience and experience. An ammeter is necessary for the measuring of the current strength, and a voltmeter for the measuring of the electromotive force, and it is also desirable to have another ammeter, reading both ways from zero, for measuring the charging and discharging current, and which can also be used as an indicator of current direction. With the exception of this last instrument which is always put directly into the circuit, it must be decided whether one prefers to measure the current strength in the main circuit or in a shunt.

Measuring in the first manner, namely the direct measuring, is decidedly preferable because of its simplicity, and therefore greater accuracy. The second method, namely the indirect measuring, is preferred where there is a large number of work places involved, and where by correct use errors of measurement through wrong connections are almost impossible. For large works there is also recommended the installation of a watt-meter for the purpose of calculating the costs in the separate departments.

Current Regulators.

As important as the measuring instruments are the current regulators, the adjustable resistances which are intended to bring and maintain the current and tension at the right values at the respective electrolytic baths. These regulators must have a wide adaptability, and a great number of steps, in order to be able to vary the amperes and the volts at the baths within a wide range, which is indispensible on account of the variety of the baths. Wire resistances with large contact points, fastened in iron frames on slate and marble, are to be preferred.

All incandescent lamp resistances and plug boxes or similar

construction must be classed as unreliable and unsuitable because of too small range of variation, poor contacts even with careful construction, and other deficiencies.

Conductors.

The conductors must as is to be seen from the preceding have a sufficient cross section of copper that the loss of voltage is reduced as low as possible. I once had the opportunity to visit a plant which lost one volt, between the source of current and the electrolytic work table, the fall amounting in this case to 25 per cent. Even in the best plants there is an unavoidable drop of voltage through contact resistance (as where the current goes from one contact surface to another) so the cross section of the copper is made from 15 to 25 per cent. greater than the calculation would require. Concerning the outside of the conductors, it is recommended to use wires or cables insulated with seamless vulcanized rubber, and then coated for protection, and fastened to large porcelain insulators. Naked wire may be strung on large porcelain insulators and covered with a coat of acid resisting paint for protection from the laboratory fumes, though there is great difficulty in preserving this protecting coat at the binding posts due to the abrasion there.

Switch Borads.

The switch board should be placed immediately over the electrolytic table, and should be large enough to contain all the measuring instruments, current regulators, and switching apparatus, mounted in such order as to be easily understood and simply operated. For protection from the dampness the whole board should be enclosed in a tight case with glass doors, which to economize space should be of the sliding order. The most suitable material for the board is white well-polished marble, free from metals, which has the advantage over slate in not being so hygroscopic. The size of the switch board depends, as also the size of the source of the current, accumulator batteries, regulators and switching apparatus, upon the kind of work to be performed, and the number of working places.

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Work Room.

After reaching a final conclusion on these questions, we are ready to consider the selection or (if building) the designing of the work rooms. There should be at least two rooms, one solely for electrolysis and for the switch board and accumulators (in an alcove) and the second room for the dynamos, with their motive power (steam, gas or water motors), or for the converter when connection is made with a central station. This second room can only be dispensed with when connection with an arc-light circuit is possible, in which case it is pre-supposed that there is a sufficient number of lamps burning all night. This is generally the case in large works.

In reconstruction and large plants designed for the purpose of instruction, four rooms should be allowed, one for the dynamo with its motive power, one for the accumulators, one for work, as electro-analysis (possibly two more for use in metallurgical and galvanic plating) and the last one for the balances and for writing purposes.

Space Requirements.

The necessary floor space for normal conditions of the engine room is 20 square metres for either steam (without boiler), gas or water power; with converters about 4 square metres; an accumulator battery of four cells furnishing 60 amperes requires about 4 square metres; and a battery suitable for metallurgical purposes and the like, that is for very heavy service about 20 square metres, if the cells are all placed in the same plane, which is desirable for an easy access. If the cells are placed in two rows, one over the other on wooden supports, only half the floor space will be required.

The work room for electrolysis will require, including the laboratory tables, about 16 square meters for four work places; and the same amount of space will be required for the metallurgical and galvanic testing equipments.

The space required for the balances can be adjusted to local conditions and the requirements of the chemist, but will require at least 16 square metres.

The rooms should lie as close as possible to each other and

communicate through doors, with the exception of the accumulator room, which should open to the outside only, so that the gases evolved cannot pass into the other rooms. To avoid loss of energy the battery room should be adjacent to the working room. All rooms should be high, well lighted and well ventilated, and be well equipped with gas and water taps at all the working places, and besides good artificial lighting each table should be equipped with a small water, hot-air or electric motor for driving stirring apparatus. With the exception of the accumulator room all rooms should be connected with the existing steam heating system, or else otherwise comfortably heated.

PART II.

In this part we will describe a limited number of existing plants for electrolysis. In order to avoid obscurities we will limit these descriptions to the more important points and, as it becomes necessary, add drawings. I could have included many other plants, but that was unfortunately impossible because of insufficient knowledge with regard to certain details.

However, it will be quite possible to draw from the examples given a picture of the manifold arrangements of this kind of plant, and in case of necessity, to construct from them general directions for the choice of the system best suited to the particular case.

At this point we will not omit to express our sincere thanks to the gentlemen who so willingly placed the information in our hands.

Aachen.

The Electro-chemical Institute of the Aachen High School, which is under the direction of Professor Classen, uses as a source of current the three-wire direct-current system of the municipal electric plant. The high tension direct current taken therefrom, of 2×108 volts is transformed by means of a rotary transformer into current of 8 to 12 volts, and is as such either directly used or is stored up in a large accumulator battery consisting of 4 elements of 60 amperes maximum discharge current and 180 ampere-hours guaranteed capacity, and thence conducted by heavy insulated wires to the twenty work places provided. Besides the large battery there is in addition a small one likewise of 4 cells and of 20 amperes maximum discharge current. The cells of both batteries may be used, if so desired, in pairs in parallel for heavy currents, or in series for tension.

Each working space carries over it a board upon which are placed the handles for the regulating resistance, the double-pole lead fuse to protect the apparatus and transformers against overloading, the cut-out switch, an ammeter switch, a voltmeter switch, as well as two binding posts marked + and — for con-

necting with the electrolytic cells. The resistance belonging to the regulating handle is placed in a closet under the table, for protection from vapor. The conductors upon the table are placed inside a double walled back-board so that only the four appara-

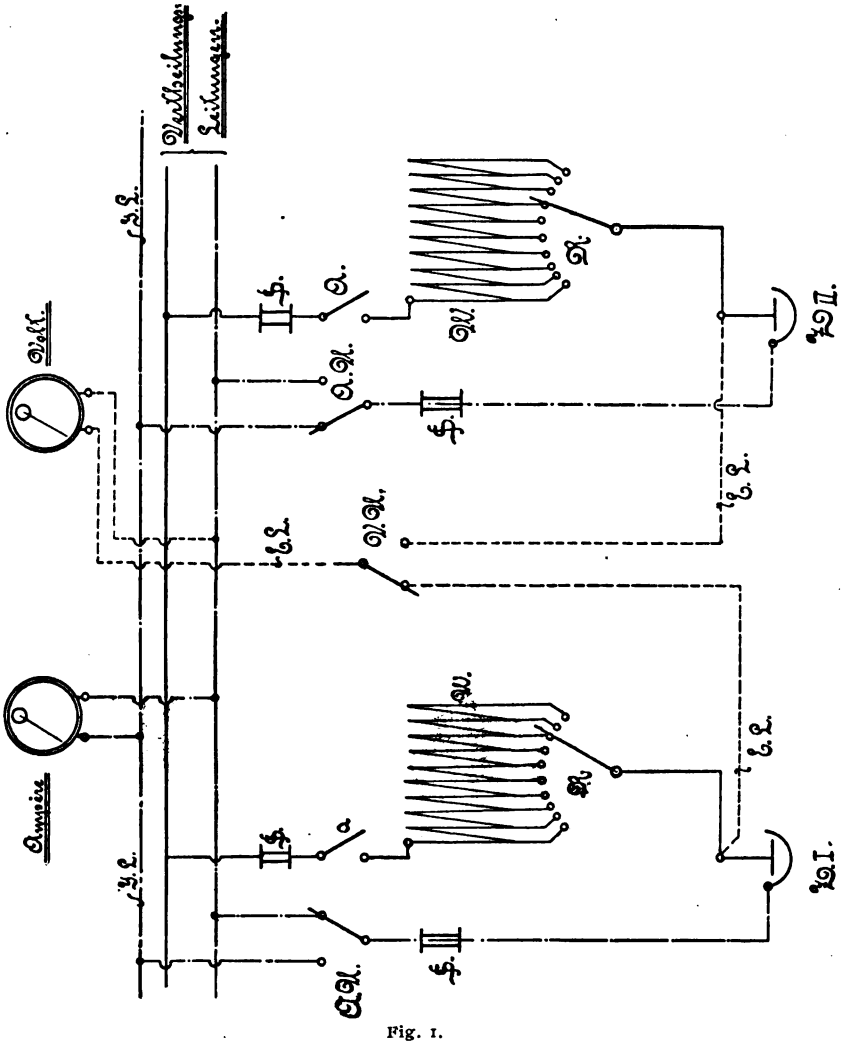


Fig. 1.

tus and the two binding posts are visible. The fuses, the main

cut-out switch and the ammeter switch are provided with protecting covers.

Each working place is provided with an ammeter with a scale from 0 to 3 amperes in both directions and divided into 0.1 ampere, and a voltmeter with two scales with a range of 0 to 5 and 0 to 10 volts respectively. These instruments are provided with particularly large scales of 16 centimeters radius, in order to make possible readings at comparatively large distances.

The connections between apparatus and instruments are set forth in the wiring plan of Fig. 1; + and — designate the main conductors coming from the accumulators. At the working places I the current goes from + through the safety fuses S to the cut-out switch A, to the resistance W with the regulator R, to the cell Z, and from there over to the other pole of the safety fuse S and to the ammeter switch A-U, and thence to —, while the voltmeter switch V-U in combination with the voltmeter wires E-L allows a measurement of tension. The measurement of the current used by the cell or of the work expended upon the bath with a determined measured current strength is shown by the position of the switches in Fig. 2. At this place the current passes from + through S-A-W-R-Z and S up to A-U, by the same path as in I; it is then, however, taken by the reversed throwing of A-U directly through the ammeter wires J-L, in this way to the ammeter.

The plant was installed by the firm of Schuckert & Co., of Nürnberg.

Breslau:

Zeitsch. f. Elektrochem., 1897–98, 552.

When the Chemical Institute of Breslau was rebuilt in the year 1896, a laboratory with 24 places for electrochemistry was installed.

The necessary current was taken from the city power plant at a tension of 110 or 220 volts and by this means and the use of a main current regulating resistance (see Fig. 2) two batteries of accumulators were charged, one of which, containing 36 cells, was used entire for particular purposes, and especially for supplying the large lecture room, while the other consisting of 30 cells (see

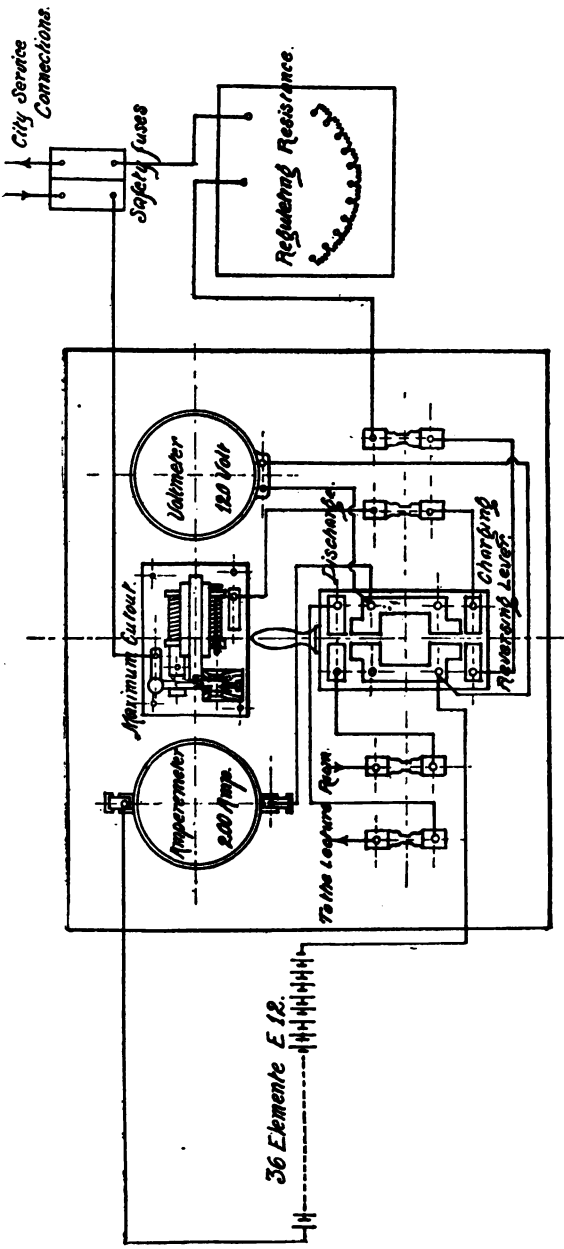

City Service Connections
Safety fuses
Regulating Resistance
Voltmeter 120 Volt
Discharge
Charging
Reversing Lever
Maximum Circuit
Ampermeter 200 Amp.
To the Logwood Room
36 Elemente E 12.

Fig. 2.

Fig. 3) was divided into several groups and served as the source of direct current for the electrochemical room. In order to be able to take varying electromotive forces from this battery five elements were united into one group, one group of which is subdivided into single cells. The poles of these single cells as those

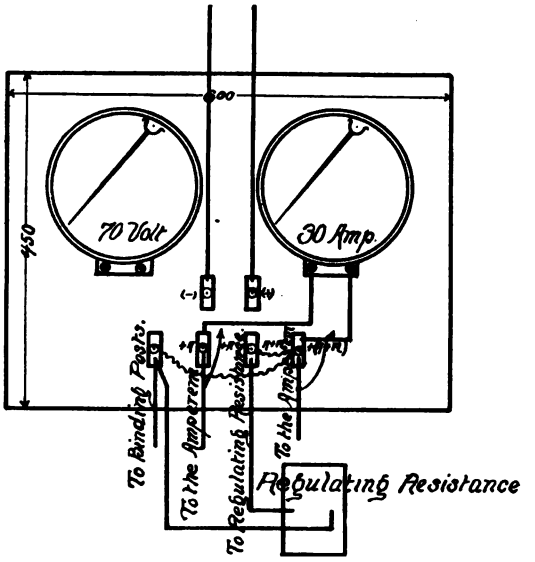


Fig 3a.

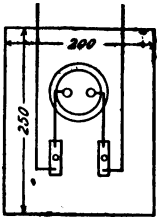


Fig. 3b

of the five single groups end at the switch-board in small brass blocks, and here end also the conductors which lead to the single work tables. Thus it is possible to connect the latter by using flexible conducting cables in many combinations with the fixed

contacts (Fig. 3a) and with the various parts of the battery so that any desired voltage may be had.

Since the five single elements of the battery will naturally be most used the switches are so arranged that this part of the battery may be charged alone. The finest measuring instruments and particular apparatus needed for investigation are placed in each case for the experimenters and arranged for use upon the working places (Fig. 3b). The measuring instruments for use with the battery are placed with the other necessary apparatus on a switch-board so that they may be used for measuring any single discharge current.

The accumulators are set up in the cellar of the Chemical Institute.

Clausthal:

Zeitschr. f. anorg. Chem., 26, 167.

The chemical laboratory of the Mining Academy at Clausthal takes its primary current of a maximum strength of 15 amperes

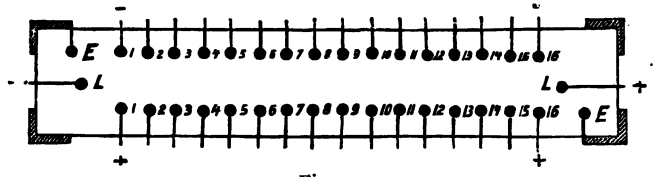


Fig. 4.

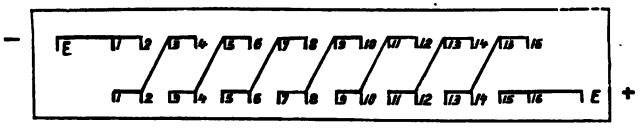


Fig. 5.

from the city circuits and either uses it directly for experimental purposes or charges with it a battery of accumulators without the introduction of any resistance but merely with the introduction of safety fuses and an automatic low-current cut-out. The battery consists of 48 cells each of 22 amperes maximum discharge current strength and 90 ampere-hours guaranteed capacity. The battery is divided into 16 single groups of 3 cells each and 32 groups of wires lead from its location in the cellar to the contact apparatus (Figs. 4 and 5.) mounted on the ground floor.

This contact apparatus consists of a switch-board 120 × 30 centimetres and 60 centimetres thick which has been boiled in

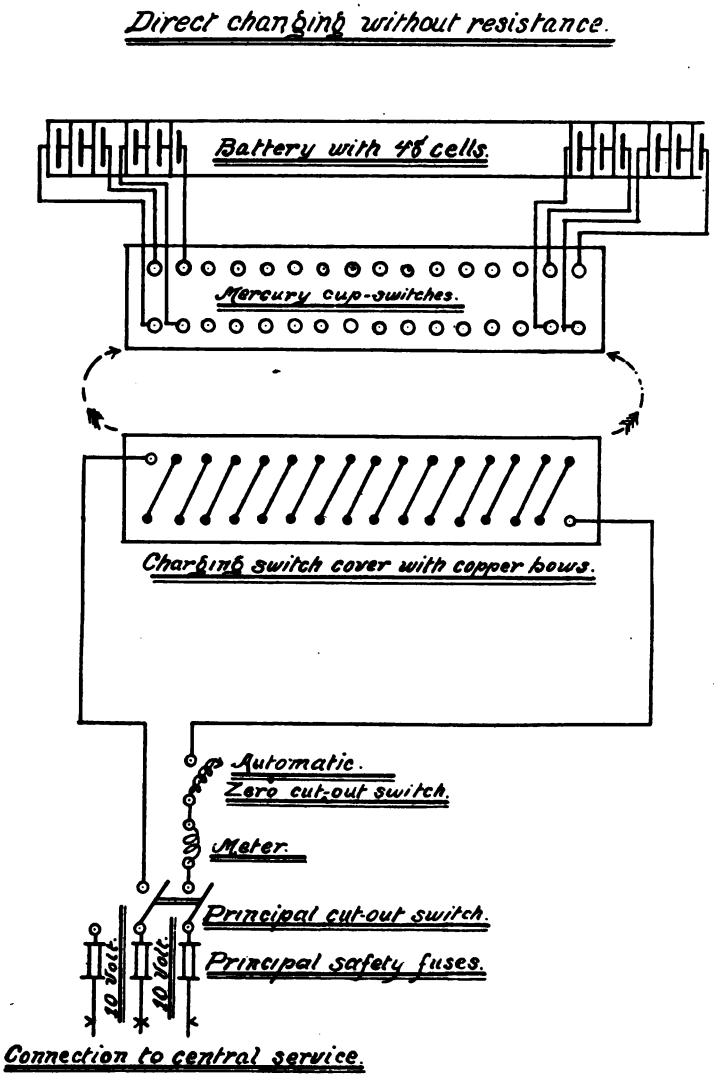


Fig. 6.

paraffin, and has 32 circular holes, arranged in two parallel rows,

corresponding to the 32 wires, and further two holes each for the principal charging and discharging conductors. These 36 holes are filled with mercury. For connecting the batteries for charging and discharging at the determined current strength of 22, 44, 88, 176, 352 amperes at 96, 48, 24, 12 or 6 volts, respectively, wooden forms are used with the corresponding labels, upon the under side of which copper bows are attached of such form, strength and position that they only need to be dropped down between corner guides upon the connection board in order to furnish the system of connection designated by its label. The wiring plan for direct charging of the battery without resistance may be seen in Fig. 6.

Two wires lead the main current to the switch-board, while others lead the discharging current to the distributing switch-board on the first story, from whence the distribution is made to the auditorium, the four work places, the private laboratory, and the iron metallurgical laboratory. For obtaining small currents at tensions under 6 volts, as well as for electrical measurements 10 small accumulators are provided, which are connected in pairs, as small transportable batteries; these are connected in series and charged over night by the large battery at a tension of 24 volts.

When carrying out an electrolytic operation a student is given a place provided with an ammeter, a voltmeter, a rheostat, and binding posts, so arranged that the necessary connections in the circuit can be easily observed. The student thus needs only to place upon his work table the electrolysing stand and to connect this with the poles of the main conductors above each working table and then proceed with his analysis.

Darmstadt.

The eletrochemical laboratory of the Technical High School at Darmstadt produces its own current in its own electric power plant placed in the basement of the building where the noise from the machinery cannot annoy any one. The plant is provided with a direct current dynamo giving either 500 amperes at 12 volts, or by changing the circuit 250 amperes at 24 volts. The cables from the dynamo machine are conducted to a main switch-

board in the same room so that all regulating and changing of circuits of the dynamo can be conveniently performed from this point. The current furnished by this dynamo is used either to charge a battery of 5 cells having a discharge capacity of 500 amperes or for a second of 36 cells of 300 amperes capacity. In the first case the armature windings of the dynamo are put in parallel so that the machine gives double current strength at single tension. For charging the 36 cell battery, the armature windings of the dynamo are connected in series; that is, to give a single current strength at double tension, and the battery is then divided into single groups. All the required apparatus and instruments are placed upon the main switch-board, to which the batteries, likewise in the cellar, are also connected by a corresponding number of conductors.

Besides this the plant also contains an alterating current dynamo of a capacity of 60 amperes at 100 volts, and a transformer for current at 10 to 1,000 volts divided into convenient intermediate intervals.

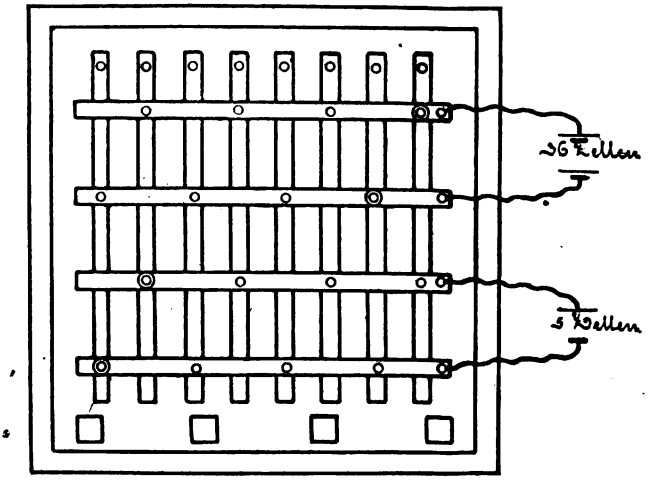


Fig. 7.

From the main switch-board the current is led to the main current measuring room on the ground floor, and is thence under skillful supervision divided up and furnished to the working places in the strength and at the tension required at the time. This

division and regulation of the current from the main power house to the working places is accomplished by means of a so-called line controller, the construction of which is shown in Fig. 7. The two lower horizontal copper strips are connected with the five cell battery and therefore give 500 amperes at ten volts tension, the two upper ones to the 36 cell battery and give therefore up to 300 amperes at 72 volts. The vertical strips are connected with the upper and lower horizontal strip by the plugs shown in the drawing and then conduct the current, after passing through lead safety fuses, by means of insulated wires to the working places. These conductors are made so large that even with the highest currents an energy loss of 5 per cent. in the conductors is not exceeded, and in this way disturbances of neighboring experiments are as far as possible avoided. In the measuring room there are also delicate instruments of precision which as needed may be placed in one or the other working circuits.

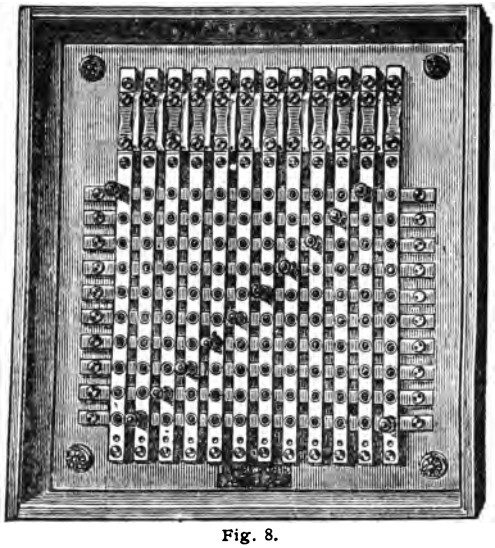


Fig. 8.

In two rooms on the ground floor and the first story above there are 40 working places. Each work table has a regulating resistance mounted in a closet under the table to protect it from vapors, and a voltmeter and ammeter which are placed in a separate glass case.

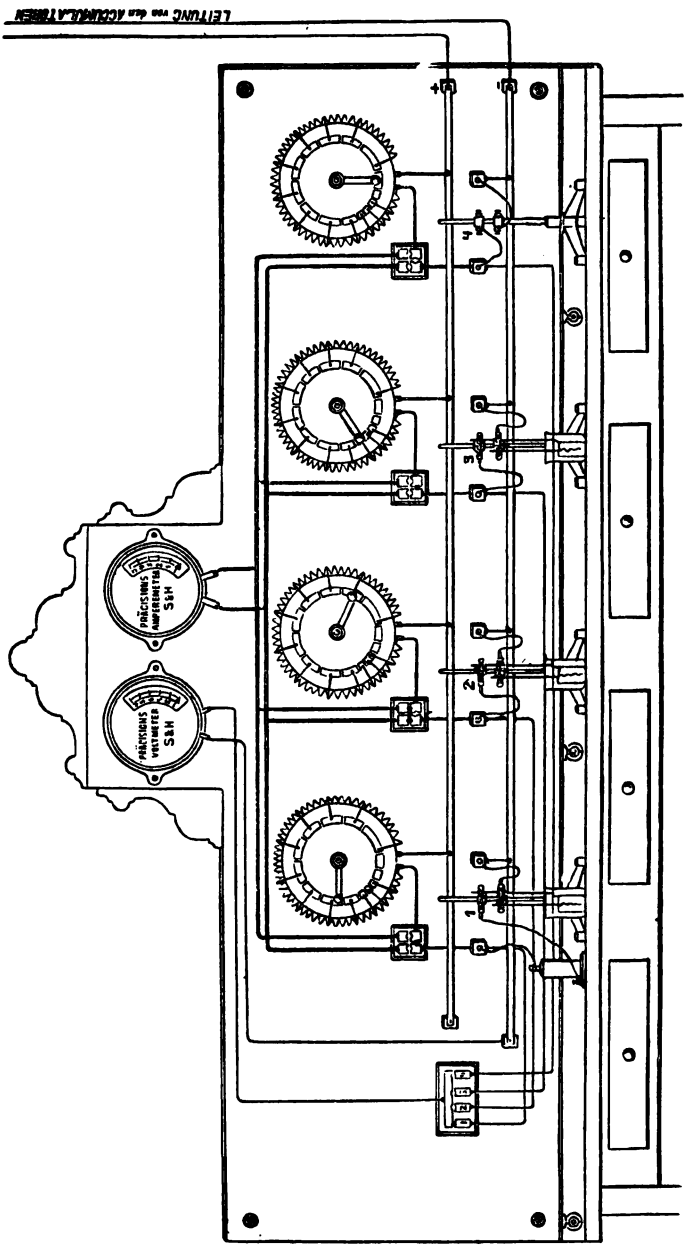

LEITUNG von der ACCUMULATOREN
+
PRÄCISIONS AMPEREMETER S&H
PRÄCISIONS VOLTMETER S&H
4
3
2
1

Fig. 9.

In general only 20 amperes are available for each working place. Yet the measuring instruments as well as the regulating resistances and the lead fuses are arranged so as to be easily replaceable in oredr that, if necessary, instruments for large currents may be put in their places.

In the private laboratory of the head of the department, Prof. Dieffenbach, there is also a large line controller, the outside of which is shown in Fig. 8. In this the horizontal strips are also connected with the source of current while the vertical strips conduct the current, by using the proper plugs, to the desired working places. For the avoidance of overloading by short circuits, etc., the distributing conductors are provided with lead fuses. This controller allows of the taking off of direct or alternating current in six different ways.

Freiberg, Saxony:

Chemiker-Zeitg., 24, 56, 1900.

The electrolytic laboratory at Freiberg, Saxony, uses a Gülcher thermopile as a source of current, and with it charges an accumulator battery of four cells.

The switch-board is placed directly above the electrolysing table and contains the following apparatus, serving for four working places: an ammeter of precision reading up to 5 amperes by 0.01 ampere and a voltmeter of precision divided as the above up to 10 volts, a circular crank regulating resistance, a plug switch for the measurement of the current, a common plug switch for the measurement of the voltage, and two binding posts for the connection of the cells.

All the conductors lie on the front side of the switch-board to show their use clearly, for which purpose they are also insulated in colors, the wires to the working rooms being green, for current-measuring are red, for voltage measuring blue, etc. Fig. 9 gives a clear idea of the equipment.

Giessen:

Zeitschr. f. Elektrochemie, 1899–1900.

At the Electrochemical Institute in Giessen, Professor Elbs erected a private plant, which uses as driving power a 16 horse-

power gas engine. This runs a demonstration dynamo which can furnish either direct or alternating current. For the electrolytic work itself (the dynamo is used also for lighting) there is an accumulator battery of 9 elements of 1200 ampere-hours capacity and a maximum discharge rate of 590 amperes, which is charged by means of a converter wound for an output of 200 amperes at 20 volts (see Fig. 10).

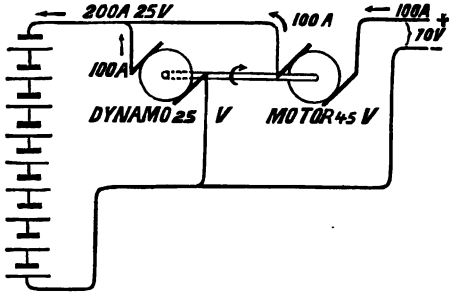


Fig. 10.

The battery is divided into three groups of respectively two, three and four cells in series, by which tensions of 4, 6, 8, 10, 14 and 18 volts may be obtained. See Fig. 11.

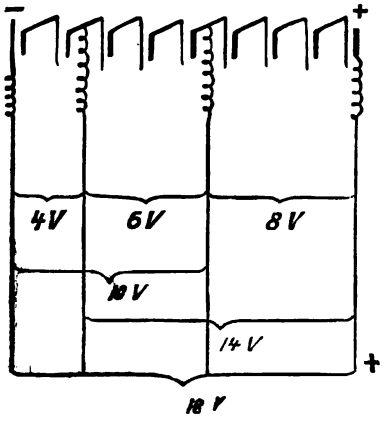


Fig. 11.

Corresponding to the above grouping of the battery four wires lead to each working place, which are calculated for a maximum current of 25 amperes.

Each working place has a three-storied superstructure for the accommodation of the regulating resistance, the ammeter and the voltmeter, and at the side of the shelves are the binding posts for the connection of the cells to the current conductors.

Desilverization Works at Hoboken near Antwerp.

This plant, used only for practical purposes, employs as a source of current, an old accumulator battery on hand at the time of remodeling, and a new one consisting of four cells with a maximum rate of discharge of 30 amperes and a maximum capacity of 132 ampere-hours, on a 10 hour discharge rate at 13 amperes. Both batteries are charged from the lighting plant at the works by the interposition of a resistance. The apparatus equipment is designed for eight working places. Fig. 12 gives a clear view of the arrangement, which will be still further explained in the following:

Three switch-boards, M_1, M_2, M_3, of white marble free from metals, are built in a large oaken frame 3 metres long and 1.25 metres high.

The measuring instruments Amp. and Volt with their switches Amp. Umsch and Volt Umsch are placed on the middle board M_2 so that they may be easily connected to and read from each working place. The voltmeter Volt is an aperiodic precision instrument with a reading range from 0 to 12 volts with a scale of equal divisions in tenths of a volt. The aperiodicity (dead beat quality) of the measuring instruments for such purposes is of great value in order that they may quickly come to rest and can be accurately read off. Connected directly with the instrument is the double-pole voltmeter switch Volt Umsch, which is placed in the middle of the switch-board M_2 because being most frequently used. The switch consists of two sectors of circles $x+$ and $x-$, which are connected to the binding posts of the voltmeter by two wires, and the 2×10 contacts be arranged in the form of an arc, of which eight with their eight diametrically opposite contacts lead by means of heavy insulated conductors of negligible resistance straight to the binding posts BK of the baths. Over the centre of the contacts is a heavy pivoted handle of ebonite which at each of its two ends carries heavy contact brushes, one sliding over the

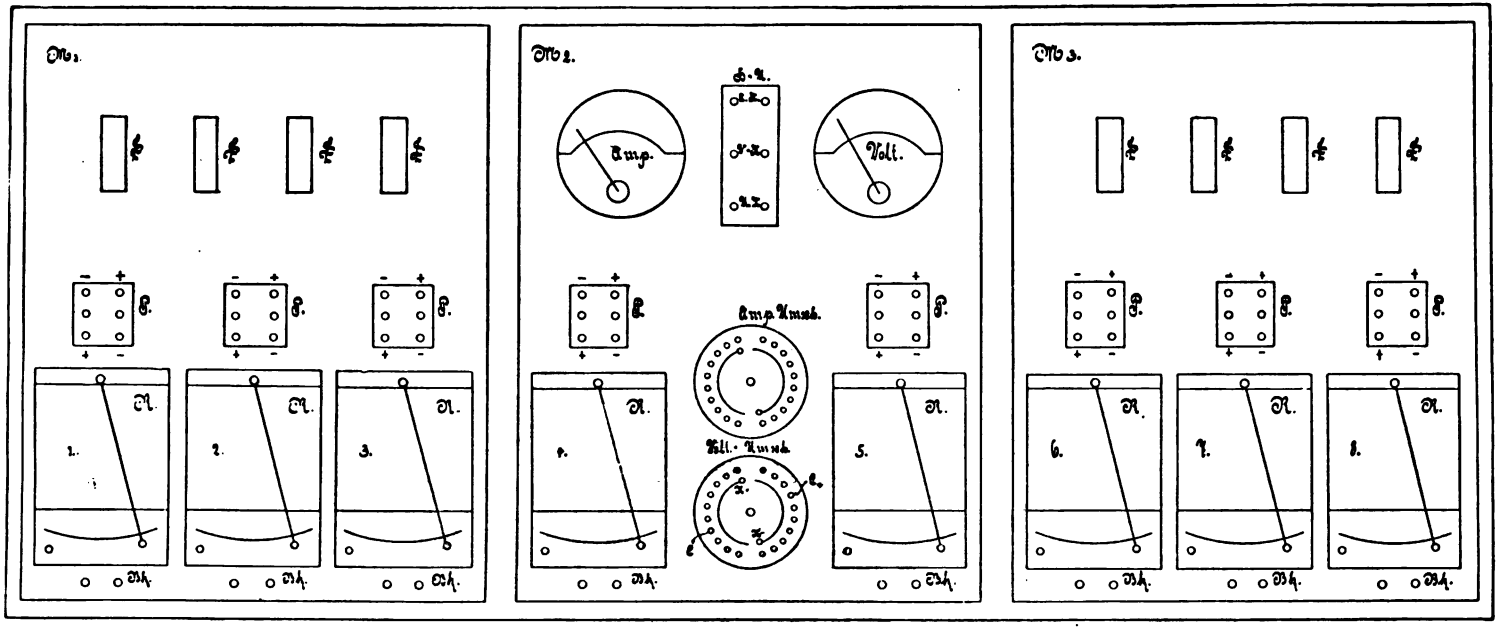


Fig. 12.

sector contacts x and the other over the contacts C and uniting these metallically directly with each other. If the handle is placed for instance in contact with C_4 then the voltmeter will indicate the tension across the binding posts of the bath 4. The contacts C_9 and C_{10} are in connection with the main switch H—U and enable the electromotive force of both the old and the new accumulator batteries to be read off.

The main switch H—U is a double-pole lever switch whose blades are pivoted at the middle clamps v x which are in connection with the distributing conductors. When the blades are thrown over to the upper contacts a x current is taken from the old battery, when thrown over to the lower ones u x the new battery furnishes the current. When no work is being performed the handle is thrown straight out at right angles to the drawing where it is held by an arrestment. Thus the switch also serves as a make and break switch. For measuring the current an aperiodic precision ammeter Amp. with a scale of equal divisions from 0 to 6 amperes and divided into 0.05 ampere is used. This instrument is not, however, used to measure the whole current directly, for by so doing larger or smaller errors are unavoidable according to the skill with which the switching plant has been built and is used. Rather it is preferable to use it as a shunt instrument traversed only by a part of the whole current. This manner of measuring is designated as indirect, and that in general use as direct measurement. Fig. 13 shows this last method applied to a single circuit, and Fig. 14 the same applied to several working places. Figs. 15 and 16 show the indirect method applied respectively to one or more working places. A comparison of the figures shows at once the superiority of the indirect method with the direct in reference to precision of measurement, especially with the application of a single concentric ammeter switch for all the baths. The greatest possible accuracy will be attained when the total resistance of the adjacent or distant bath-circuits remain unchanged whether the ammeter is in circuit or not, which is attained by putting the ammeter of relatively higher internal resistance by means of the ammeter switch only in shunt at the terminals of standard shunt resistances S introduced into each current circuit. These shunt resistances are all alike and of

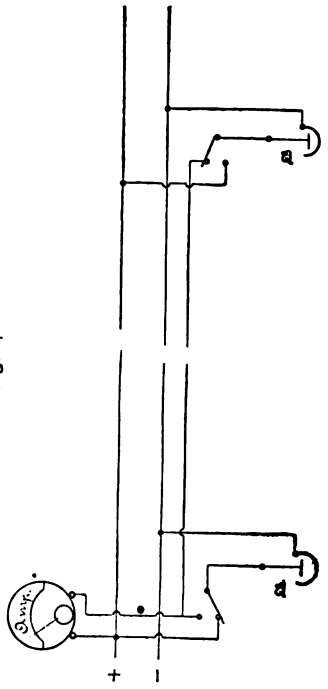


Fig. 14.

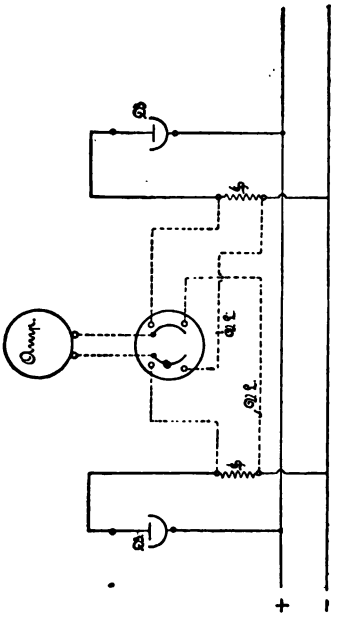


Fig. 16.

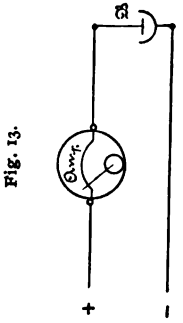


Fig. 13.

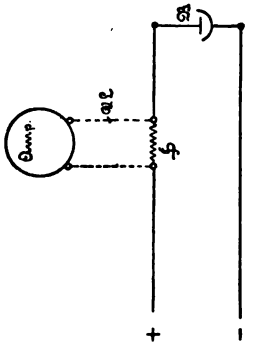


Fig. 15.

very small resistance which bears an accurately determined relation to the resistance of the measuring instrument, so that the measuring instrument is traversed by a certain fraction of the current passing through the bath, the latter being calculated by the formula,

$$J_m = \frac{J_v \cdot W_s}{W_m + W_s},$$

in which Jm is the current flowing through the instrument, Jv the current passing through the bath, Ws the resistance of the shunt, and Wm the internal resistance of the instrument.

To attain really accurate results it is indispensible that the conductors between Amp. and Amp. Umsch on the one side and Amp. Umsch and the shunt on the other side should have exactly the same very small resistance, for which purpose this resistance should be determined before they are fastened to the switch-board. The double-pole ammeter switch, which is constructed exactly like the voltmeter switch Volt Umsch, avoids absolutely the danger of the error that the sum of the current strengthrent strength of two given baths may be measured for one, because the lever of Amp. Umsch can only touch the contacts of a single bath at one time.

Besides the above described apparatus the switch-board carries eight reversing switches, eight bath-current regulators and eight pairs of bath binding posts which according to the space available are divided among the marble tablets M_1, M_2, M_3.

The double-pole reversing switches serve for reversing the current, a requirement which is necessary in certain cases, and which saves the annoyance and time-consuming disconnection when by oversight the bath is connected up wrongly, which often happens in practice. The arrangement of the poles is the same as in the above described main switch H-U, only it is smaller because of smaller currents. The middle terminals lead the current away to the baths, the upper and lower ones bring the current; above the right one is + and the left —, below the right —, and the left +.

The bath current regulators have in the case in question a total resistance of 40 ohms divided into twenty, some large, some small steps.

They consist of rectangular cast iron frames on which are strung resistance spirals which are connected in suitable sections with contacts arranged in the form of an arc of a circle on a slate board. In order to regulate these resistances, there is pivoted a long contact arm of large radius, and therefore easily moved, upon a fixed axis at the opposite end of the frame, the axis serving likewise as a contact. Underneath the regulators are the binding posts BK for the baths from which flexible double cables covered with rubber lead to the stands. The two wires of the double cables are differently colored so as to differentiate their polarity. The whole installation including the return conductors is protected from the laboratory fumes by a tightly closed oak case from which only the last named double cables lead out. Three tightly closed glass doors are placed on the front of the case, through which the measuring instruments and their connections may be seen.

Beneath the apparatus case there is hung a case of shelves, which are covered with thick glass plates for protection from damage by acids. The case, as made by me, had two shelves arranged step-like one above the other. On the lower one, after the electrolysis is complete, a glass vessel can be placed into which the electrolyte can be siphoned in a simple manner.

The installation was designed and built by the firm of Raacke Brothers, of Aachen, in the fall of 1899, who packed it in such shape that it was only necessary to hang the shelves and closet in place in order to be at once ready for use.

Königsberg.

The present electrolytic installation of the Chemical Institute at Königsberg was completed in the winter of 1899/1900 under the direction of Professor Blochmann. It is arranged for four working places.

The source of current is an accumulator battery of four cells of the same capacity as those at Hoboken which are charged from the city plant through resistances. The measuring and the switching arrangements are the same as those at Hoboken, except that here a second ammeter with a large-range scale is permanently placed in the main circuit without an individual cut-out switch

and serves for the control of the current consumption of all the baths.

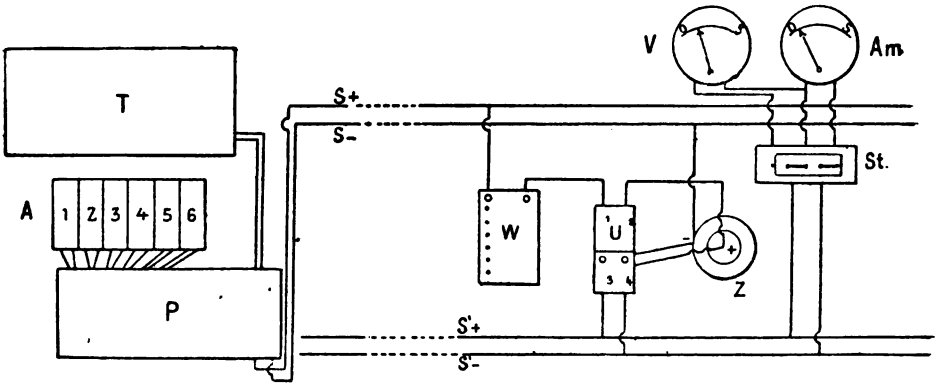
The accompanying figure, Fig. 17, shows the external arrangements of the installation.

Raacke Brothers of Aachen designed and installed the plant.

Loeben:

Österr. Zeitg. f. Berg. u. Hüttenwesen, 46, 1898.

The laboratory equipment of the Imperial Mining Academy at Leoben demonstrates that it is possible to carry out investigations on a small scale in such places as are without a city power supply or one of their own for the disposal and distribution of the current. A Gülcher themopile is used as the source of current; it consumes 170 litres of gas per hour and gives a current of 3 amperes at 4 volts.



Pachytrop.

Fig. 18.

Six accumulator cells are charged by this, each having a discharge rate of 2 amperes and a capacity of 18 ampere-hours.

For connecting the cells for tension or current strength, or connecting singly or in groups in parallel or series, the Institute uses a so-called Pachytrope after Daurer. Such a Pachytrope consists, corresponding to the number of cells concerned, of a number of contacts mounted on an axle, and capable of being rotated by means of a handle, sliding between metal teeth which connect

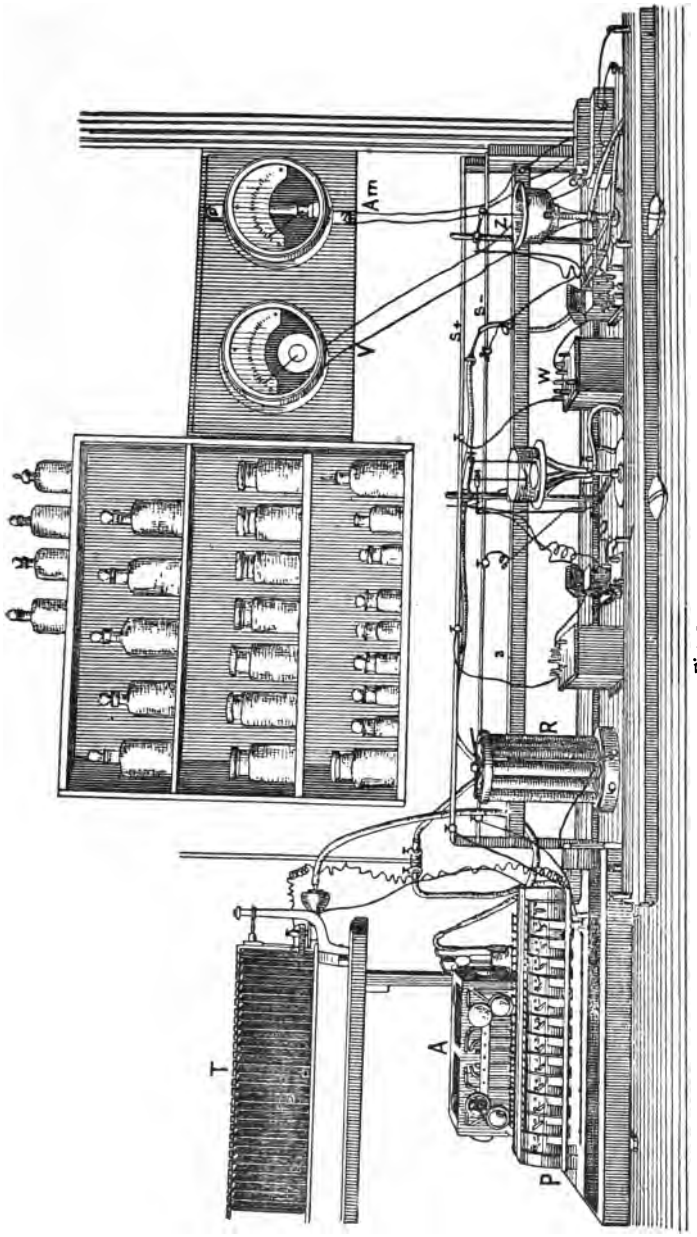


Fig. 19.

copper segments. According to the distance which the discs are turned and according to the use of certain discs, one can have at his disposal the desired current at the desired tension.

From this switching arrangement the current is conducted to two working places which are on the same table with the above described apparatus. Both working places have a plug resistance box and a double-pole mercury switch, one side of which connects the cell with the voltmeter and the other side with the ammeter. Both measuring instruments together with a rack for reagents are on the wall over the table, so that the total equipment is assembled above and upon this one table. Figs. 18 and 19 present a clear outline of the scheme of connections and equipment.

Central Laboratory of Dumont Brothers, Lüttich.

The equipment for electrolysis in this case is likewise for the practical purposes of a laboratory connected with a large metallurgical works and is built after the same principles as that of Hoboken. Differing, however, from the latter are the means for producing current, which will be described more in detail here. Aside from this Fig. 20 shows the equipment intended for six working places.

The laboratory uses as a source of current the existing connections for lighting purposes to the city lighting plant of 2×105 volts direct current (three wire system). The current taken from the outside conductors of the three wire system at A (see Fig. 21) at 2×105 volts tension, passes first through a double pole lead fuse B, a double pole main switch HA and the wattmeter Z; from here it is led by rubber covered wires of copper having a cross section of 5 square millimeters, and carried by porcelain insulators, to the transformer switch-board T-S in room I (see Fig. 22) and then conducted to the converter T through the regulating resistance A-W.

The converter is of the rotary type, consisting of a direct current shunt wound motor rated at one horse-power at 220 volts and mounted on the same cast iron bed plate with a direct current shunt wound dynamo to which it is directly coupled through a flexible leather coupling, and which at 1000 revolutions per minute furnishes 40 to 50 amperes at 12 to 9 volts tension. The cur-

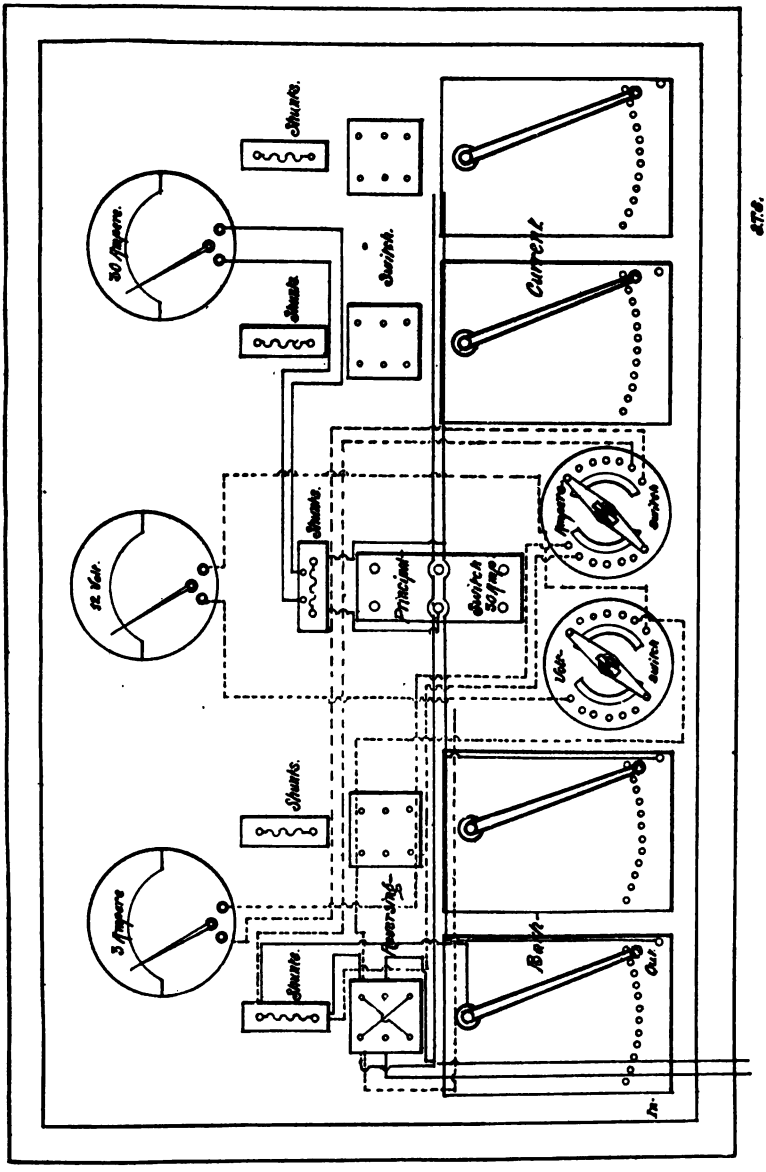

Shunts.
30 Ampère.
Shunts.
Switch.
Current
12 Volt.
Shunts.
Principal
Switch 30 Amp.
Ampère
Volt-
3 Ampère
Shunts.
Reversing
Battery
Out
In

Fig. 20.

rent from the dynamo is regulated by the use of a shunt controller either for direct use at 8 volts or for charging storage batteries at 12 volts, and then passes through a double pole 50 ampere fuse from which point it is led over to room III by rubber covered copper conductors of 35 square millimeters cross section strung on large porcelain insulators. In the same room in an alcove A-K is the accumulator battery A-B. This consists of four cells with a maximum discharge rate of 30 amperes and a maximum guaranteed capacity of 132 ampere-hours when discharged at the rate of 13 amperes for ten hours.

In general the accumulators are used for electrolysis because of their constant tension, and are charged as follows. First, the switch HA is closed into the main line and then gradually by means of the starting resistance AW the motor side of the converter is cut in until the latter is at full speed and then the shunt regulator KR of the dynamo side is brought into circuit until the voltmeter registers 12 volts. The charging switch L-S on the main switch-board is now closed and the charging begins, the current strength being controlled according to the indications of the ammeter. This instrument of precision is of the same type as those used at Hoboken and has its zero point in the middle of the scale so that it can also be used at the same time as an indicator of the direction of the current; that is, when the needle points to the right the battery is charging, when to the left it is discharging. In order to use the instrument to better advantage it is connected to the ammeter switch, so that it is possible by turning the handle, to switch on to a shunt on the bath circuit, and so with the same to measure the total current simultaneously used by several baths whether they are taken directly from the dynamo or indirectly from the battery.

If it is necessary to perform electrolysis during the charging of the battery the main switch is thrown over to the right, and there is received the direct current of the dynamo at the charging tension used. This method of operation is recommended as economical, because in this way a loss of energy in the accumulators amounting to 20 per cent. is saved, aside from the excess voltage necessary for charging. This overvoltage which has to be neutralized in the bath circuit regulators ceases as soon as the charging

of the battery is ended, and when after opening the charging switch L-S the dynamo tension has been reduced to the desired value. These two methods of working with direct dynamo currents should, however, only be used if the chemist himself is present and by adjusting the regulator can compensate for alterations of tension originating from the city supply (which during the charging will unavoidably occur and produce a change in the current strength.) An electrolysis can be left over noon only with safety when using the accumulators, in which case the main switch is thrown over to the left to the battery, and then the desired tension and current is placed on the bath, or baths. If the battery has been just charged or is still nearly laden, then the electrolysis can be left without anxiety. All the other apparatus of Fig. 20 is the same and the connections are the same as in the installation at Hoboken, and they are also indicated by the same letters as in Fig. 12.

The equipment was furnished and erected by Raacke Brothers, of Aachen, and has been in operation since January, 1901.

Munich.

The Electrochemical Laboratory of the Technical High School of Munich possesses an electric plant driven by steam. The electrical equipment is as follows:

A direct current dynamo rated at 125 amperes at 60 to 90 volts, and used for charging a large battery and for smelting experiments.

A direct current dynamo rated at 80 amperes at 30 volts or by switching around the windings 40 amperes at 60 volts, and is generally used for charging the smaller battery.

A dynamo for the generation of single phase alternating current of 30 amperes at 50 volts, and which takes its exciting current from the accumulators.

A transformer for changing the voltage to 2-5-10-100-1,000 or 10,000 volts.

The dynamo with the boiler and engine are placed in the cellar, the switching and regulation being accomplished at a switchboard on the same floor as the laboratory. On the ground floor

above is a large accumulator battery of 30 cells with a capacity of 180 ampere-hours, and a small battery of 4 cells and capacity of 120 ampere-hours.

The large laboratory on the first floor has 27 working places which, with the exception of two, contain no other apparatus than the plug contacts for connecting the decomposing cells. The switching in and out and measuring and regulating of the current

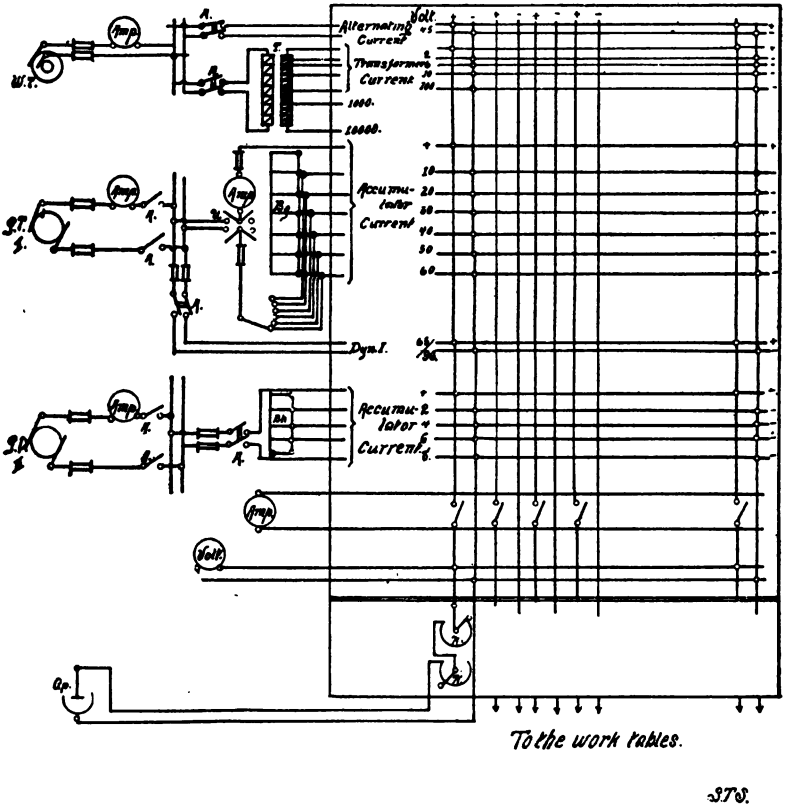


Fig. 23.

for all these working places takes place in the adjoining switching and measuring room. Only the so-called general table No. 9 and a single table in an alcove possess each their own current regulators at the place and the first several small measuring instruments for direct and alternating current.

For distributing the current there is a large switch-board which covers one whole side of the above mentioned switching and measuring room. (See Fig. 23). It consists of a black slate board containing 29 horizontal copper strips for bringing in the current and 2 × 27 vertical strips, corresponding to the number of working places, for leading off the current: each is mounted, with a small space between. The latter are provided with a suitable number of tapped holes so that one can obtain at each working place current of the desired tension and strength from each of the sources which are provided; that is, either with direct current 60 to 90 volts (direct from the dynamo), alternating current of 50 volts, the same transformed from 2 to 100 volts (the tensions of 1,000 and 10,000 volts are not accessible to the student), and also with accumulator currents of 2 to 8 or 10 to 60 volts. Underneath this system of strips are 12 crank current regulators mounted upon projecting brackets, and which may be connected with the respective working places by screw plugs. Each regulator has two contact circles with swinging cranks, capacity 12 amperes; the one for interposing resistance from 0.1 to 10 ohms, and the other from 10 to 50 ohms; so that any resistance from 0.1 to 50 ohms can be switched into the circuit, thus satisfying widely varying requirements.

The institute possesses a special room for fine measurements, there being at disposal an Edelmann's absolute electrotechnic galvanometer for 200 amperes, and a Siemens' torsion galvanometer for 0.01 to 170 volts. The same room also serves for the preparation of ozone and Röntgen investigation. [The production of ozone in the room where standard instruments are kept is not recommended by the translator.]

We must not overlook the fact that the laboratory is ventilated by three large electrically driven Blackmann ventilators.

The dynamos were furnished respectively by Schuckert, General Electric Company, and Siemens, and the switching and conducting equipment was furnished and installed by the General Electric Company.

University of Pennsylvania.

Elektrochem. Zeitschr., 8th year, No. 9.

The electrochemical equipment of the Chemical Department of

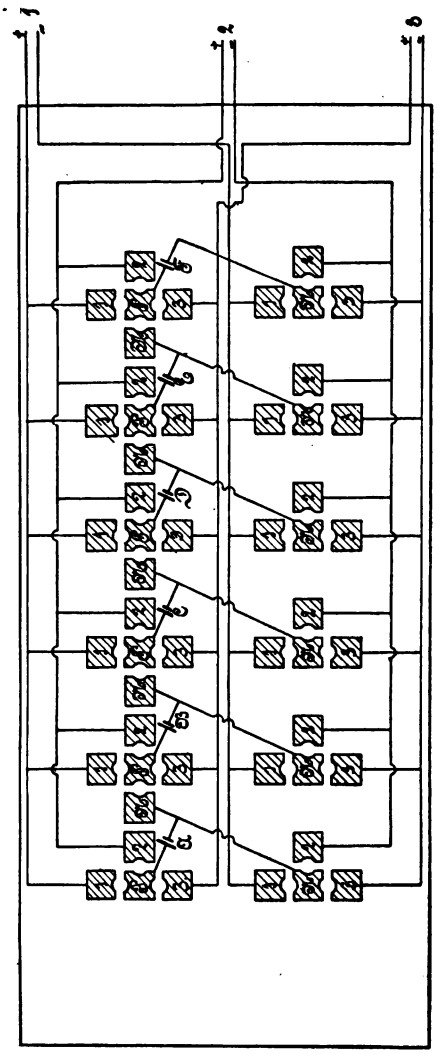


Fig. 24.

the University of Pennsylvania has been in use since the year 1878, and at that time, as was the case with all the older installations, used for the source of current primary cells. Owing to the inefficiency of these cells and also to the development of the secondary elements (accumulators) to a state applicable to practice,

a battery of cells of the Julien type was installed in 1888, and was afterwards replaced by a number of chloride accumulators.

The switching arrangement (Fig. 24) of the older plant is interesting. The figure shows only a portion of the whole (because of the limited space) but it is enough for our purposes of explanation.

A to F are secondary elements, whose positive poles are connected when in use to the contact blocks P in the upper row, and whose negative poles are when in use connected with the contact blocks N in the upper and lower rows. The connection of the working places, 1 to 3, to the cells is effected by contact plugs. If one wished to work at place 1 and required 4 volts, a plug should be put in the upper row between P and 1 of the first set, and a second between N and P of the following group in the under row. In this manner the place 1 receives its current from the cells A and B in series. If, now, place 2 requires this same tension, but double the current strength for its investigation, the cells C, D, E, F are connected two and two in parallel and the two groups in series as follows: above, in groups 3 and 5, plugs are inserted between P and 2; below, in groups 4 and 6, between N and 2; and finally above (for series connection), in groups 4 and 6, between N and P. It is clear that with this arrangement many mistakes will be made by the student which will damage the battery by short-circuiting. For a larger number of working places than three the confusion will become worse, quite aside from the fact that the integrity of the many contact surfaces will be injured by acid vapors.

In charging, all the cells are connected in series and during the night placed in series with a bank of lamps directly in a 110 volt lighting circuit. For the regulation and measurement of the electrical energy, portable resistances and measuring instruments were supplied to the working places.

The inadequacy of this equipment was soon recognized, and in time as the number of students in electrochemistry became larger, it was replaced by a new outfit. This contains 16 working places in a room having 40 square metres of floor space. As a source of current two rows of 24 accumulator cells were used

they having a normal discharge rate of 15 amperes (maximum 30 amperes) and a capacity of 120 ampere-hours.

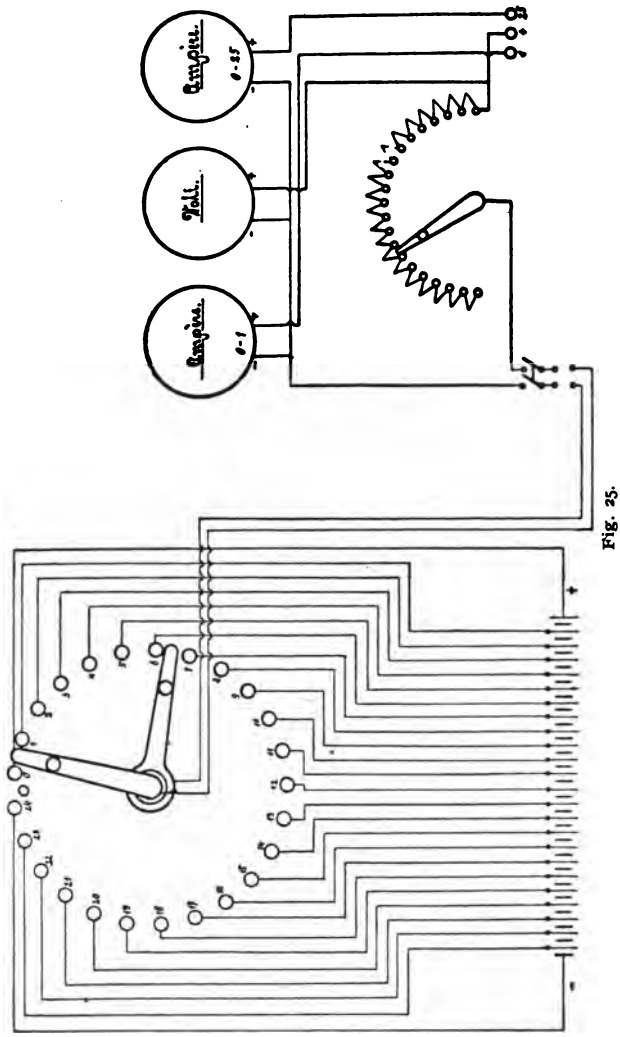


Fig. 25.

The new scheme of connections is shown in Fig. 25. Each working place has a battery controller, shown to the left in the figure; all the controllers being mounted upon 2 enameled slate

switch-boards at the head of the room. Each of these consists of a contact circle of 24 knobs, each knob in connection with a cell of the corresponding row of the battery, over which revolves two arms insulated from each other. These lead off the current at the desired tension to the working places indicated at the right of the figure. In these conductors for protection against overloading—also on the switch-board—are double-pole fuses and a double-pole switch to cut out the concerned working place, all plainly seen in the figure. Each work table is provided with a semicircular current regulator, a voltmeter and two ammeters. The first has a total resistance of 172 ohms with steps in geometric ratio. The voltmeter has a measuring limit of 0 to 50 volts divided to 0.5 volts, the ammeter, 0 to 1 ampere divided into 0.01 ampere and the other, 0 to 25 amperes divided into 0.2 ampere. Accordingly as the student wishes to use small or large currents he connects his bath between + and 1, or + and 25. The measuring instruments are fixed in a permanently closed glass case for protection from fumes, so that the only exposed apparatus in the laboratory are the controllers, the regulators and the terminals.

Besides the two switch-boards spoken of, there is still a third for four extra places so arranged that one can work with the full tension of all the whole 2×24 cells, or 96 volts. A parallel arrangement of the batteries is not provided since the maximum discharge current, about 30 amperes, suffices for the regular work of the student.

Central Laboratory of the Stock Company of Stolberg and Westphalia at Stolberg, Rhenish Prussia.

The three plants at Hoboken, Lüttich and Königsberg, and several others not mentioned here, sprung from the electrolytic plant in my laboratory, which was first erected in its primitive form in 1883 and remodelled in 1892 and 1899. These reconstructions were erected under my direction, by the Raacke Brothers, of Aachen, upon the basis of my accumulated experience, the following form having been in use since 1889.

The local arrangement of the apparatus board, the electrolysing tables and the accumulator battery are shown in Figs. 26 and 27. It is particularly worthy of notice that the accumulators are

placed in a communicating room so that, in charging, the acid fumes set free can be removed without vitiating the air in the laboratory. The battery is accessible through glass doors into the communicating room. The apparatus board is let into a recess at the end wall of the electrolytic laboratory. By this arrangement floor space is saved, and, for protection from the laboratory fumes, it is encased by sliding windows; and, finally, the leading in and connecting wires to the instruments are easily accessible

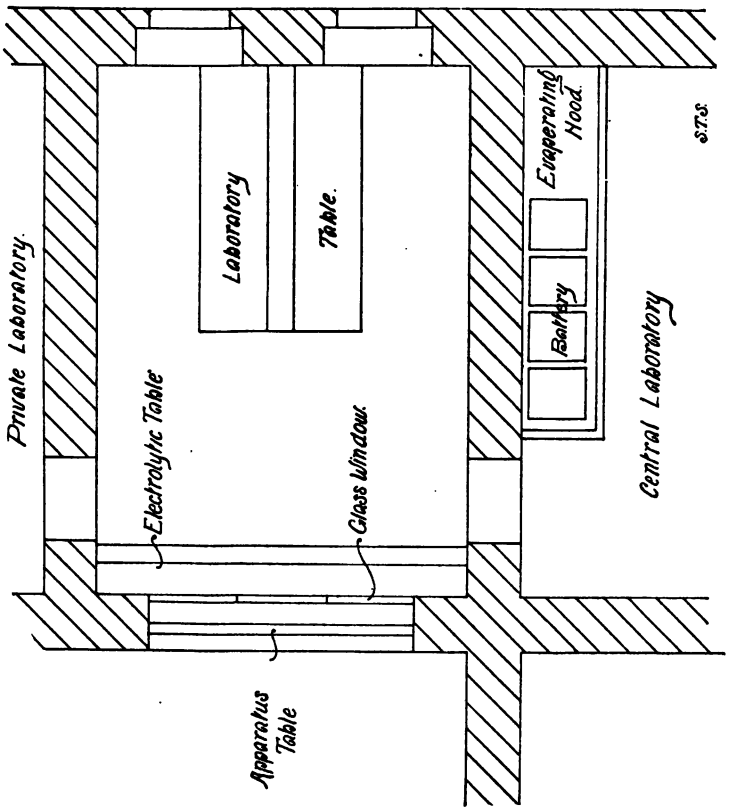


Fig. 26.

at all times without disturbing their operation. This last condition is advantageous where unusual work is frequently done, which requires unusual arrangements of the connections.

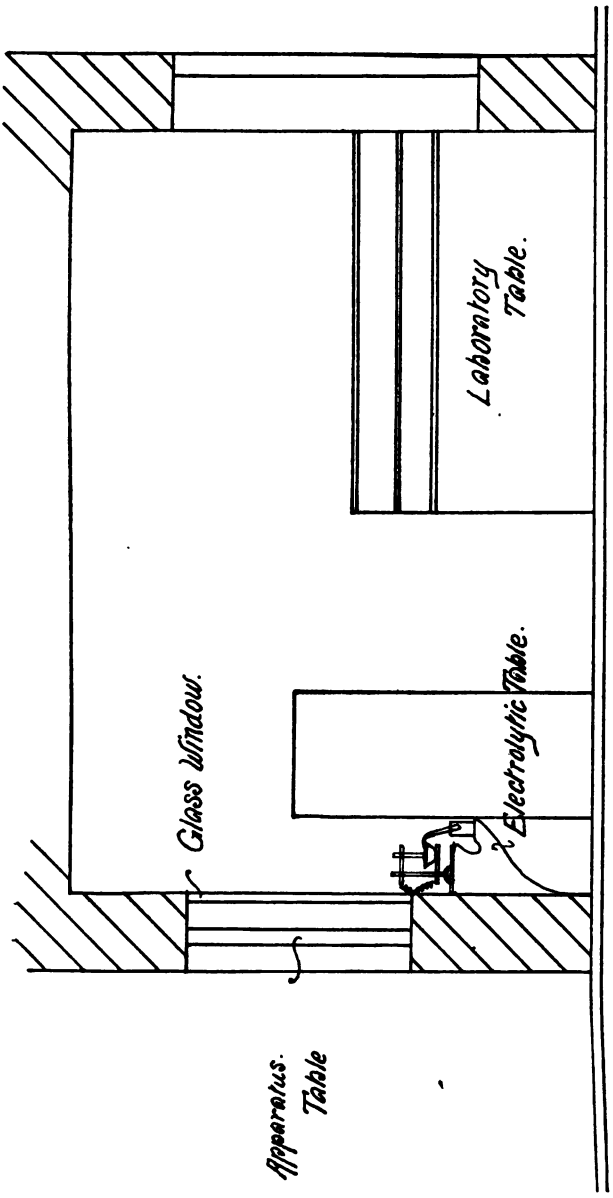
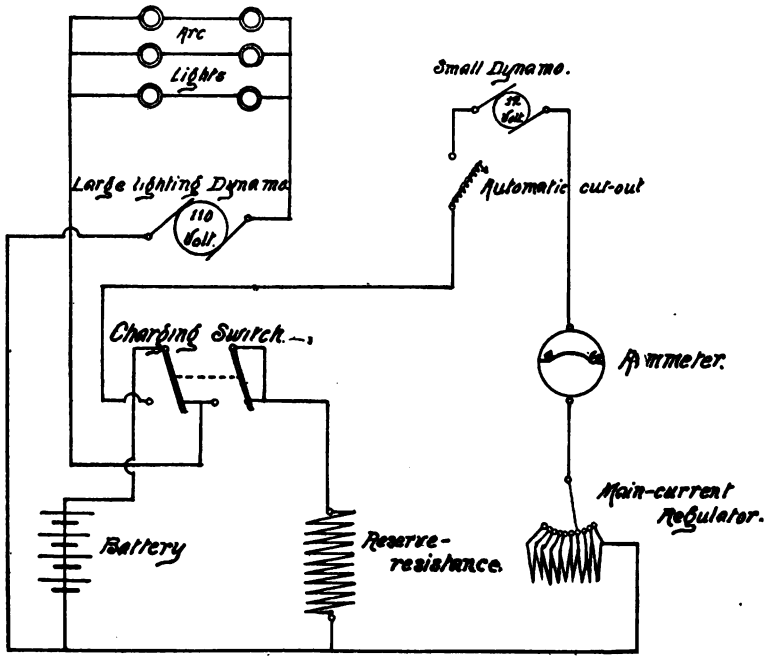

Laboratory Table.
Electrolytic Table.
Glass Window.
Apparatus. Table

Fig. 27.

The construction of the analytical work table is well adapted to its purpose. The characteristic of the same is the shelf-like arrangement of the two table tops, the upper one 20 centimetres above the lower, so that the electrolytes can be emptied out of the vessels right on the spot by means of a simple siphon.

As a source of current the plant uses:



Charging Plan.

Fig. 28.

1. A shunt wound dynamo rated at 60 amperes at 12 volts. This is directly coupled to a small high speed steam engine made by Daevel of Kiel, and has a current regulator and voltmeter arranged close by the machine. Because of the arrangement of the steam pipes at the time, the engine was unfortunately placed some 60 metres from the laboratory. The current was led over through a bare copper cable of 100 square millimetres cross-section which

was strung on porcelain insulators. This machine installed in 1892, is, however, because of the great distance at which it was placed and the troublesome service thus involved, only used as an auxiliary.

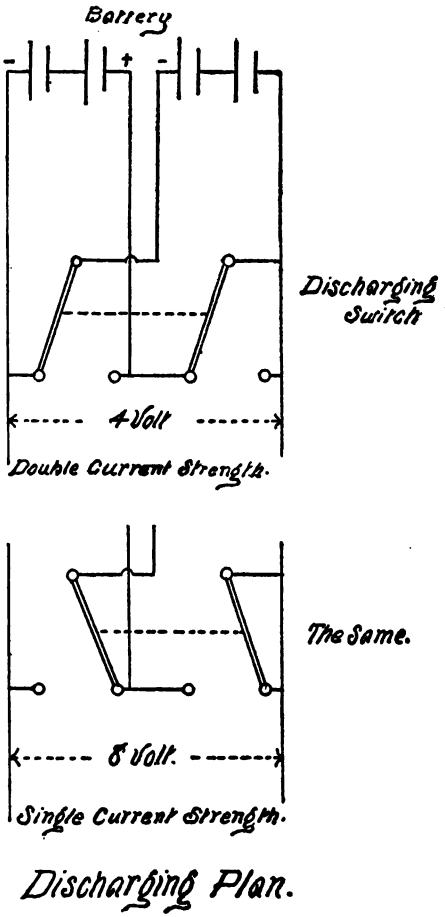


Fig. 29.

2. In the year 1897 a 50 horse-power engine and dynamo for lighting of the zinc works, the work rooms and the rolling mill was put into service and this furnished current the whole night.

The lighting plant was run at 110 volts, which is naturally too high for the charging of accumulators. The reduction of the voltage was accomplished in a simple manner; six of the 600 candle-power arc lamps of this plant were used as resistance and their current led to the battery for charging by means of a common conductor. If no charging was going on the place of the battery was taken by a corresponding resistance thrown into the lamp circuit by means of a double-pole charging switch. The arrangement of the connections is shown in Fig. 28. The arc lamps are connected in pairs in series absorbing each 90 volts, and the remaining 20 volts of the 110 volt plant is in general carried by the resistance, or in other words uselessly converted into heat, and so its use for charging the battery costs practically nothing. By the use of only six lamps in the above manner the battery was not overloaded during a night. The battery, discharged during the day, was charged at night so as to be ready the next morning.

3. As the secondary source of current there was used the previously mentioned accumulator battery consisting of four—two pairs in series—cells of the Cologne Accumulator Works of Gottfried Hagen, of Kalk, near Cologne, with a capacity of

252	ampere-hours	with	25	amperes	discharge	rate	in	10	hours,	
224	"	"	"	32	"	"	"	"	7	"
210	"	"	"	42	"	"	"	"	5	"
178	"	"	"	60	"	"	"	"	3	"

From the battery four wires lead to the double-pole discharge switch on the apparatus board by means of which the two pairs of cells can be connected in series or parallel, and so obtain a double current at 4 volts, or a single current strength at 8 volts, the normal discharge rate. During the charging the cells are connected in series. The scheme of these connections is clearly shown in Fig. 29.

We now come to the real apparatus equipment itself; its exterior is shown in Fig. 30 and a scheme of the connections in detail in Fig. 31, which will be described later.

The apparatus has to perform the functions of distributing and regulating the electrical energy as follows:

(a) charging the accumulators by the small dynamo,

(b) charging the accumulators by the large dynamo,

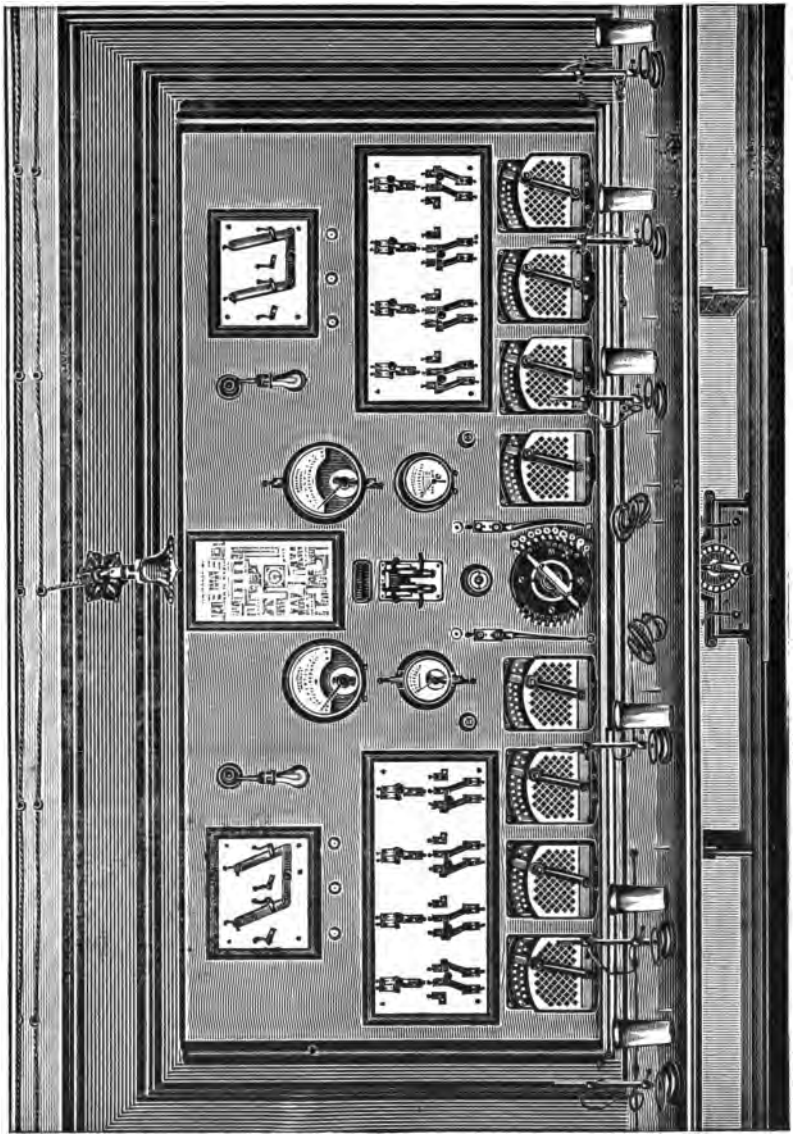


Fig. 30.

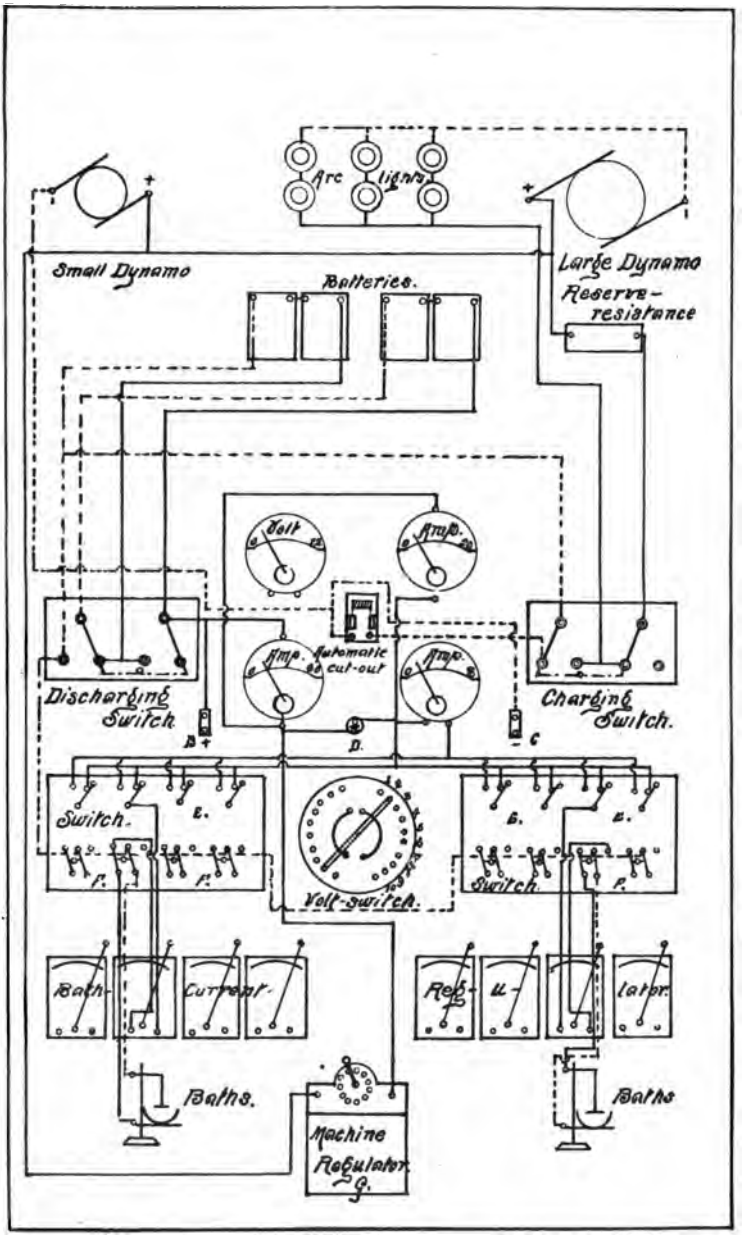

Arc lights.
Small Dynamo
Batteries.
Large Dynamo
Reserve-resistance
Volt
Amp.
Amp.
Automatic cut-out
Amp.
Discharging Switch
Charging Switch.
B
D.
C
Switch.
E.
F.
F.
Volt-switch.
E.
E.
Switch.
F.
Bath-
Current-
Ref-
-ence
Lamps
Baths.
Machine Regulator
G.
Baths

Fig. 31.

(c) principally to discharge the battery; for instance, in electrolysis.

The apparatus for *a* and *b* and their functions have already been explained, and it now remains to be said that the current from the small dynamo can be regulated from the laboratory by the dynamo regulator G, and its current can be read off upon the large ammeter up to 60 amperes; and that, further, an automatic minimum current switch protects the dynamo from reverse currents of the battery. Direct dynamo currents can be taken from the terminals B and C, eliminating the battery from the circuit. In designing the plant for the purpose named under *(c)* it was kept in mind that not only the current strength and tension of each single bath must be measured, but also that of all; and that in many cases it is desirable to be able to alter the direction of the current in the baths without changing other conditions.

For measuring the voltage there is used a Hartmann & Braun voltmeter with scale divided from 0 to 12 volts, connected to a double-pole voltmeter switch with 10 contacts; the contacts 1 to 8 being used to measure the voltage at the eight baths, 9 the voltge of charging or discharging the battery and 10 the voltage of the small dynamo. The total charging or discharging current is measured by a large ammeter divided from 10 to 60 amperes, or, in case it is under 10 amperes, upon the instrument reading from 0 to 10 amperes in series with the first. In this case the switch D on a shunt with the latter instrument is opened, and in the other case, when the current is above 10 amperes, it is closed. In order to measure the current consumption in each single bath without the use of as many ammeters as baths the switch E is provided. It is a double-pole fork switch without interruption of the current. If this stands in the position as shown in Fig. 31 then no current will flow through the smallest ammeter of 0 to 3 amperes, but rather it flows through the 10 ampere instrument to the baths. If it is wished on the contrary to measure the current used in one bath then the corresponding switch lever is placed upon the free contact, Fig. 32, and the bath current in question is forced to pass through the small ammeter.

For regulating the energy supplied to the baths there is in each circuit an adjustable resistance with 21 steps. After leaving this, the current has to pass through the double-pole reversing switch F, and finally to the baths.

In order not to complicate the drawing unnecessarily in Fig. 31 the connection of the current with only two baths is completely shown, and for the same reason the connections to the voltmeter are omitted, this being clear without further explanation.

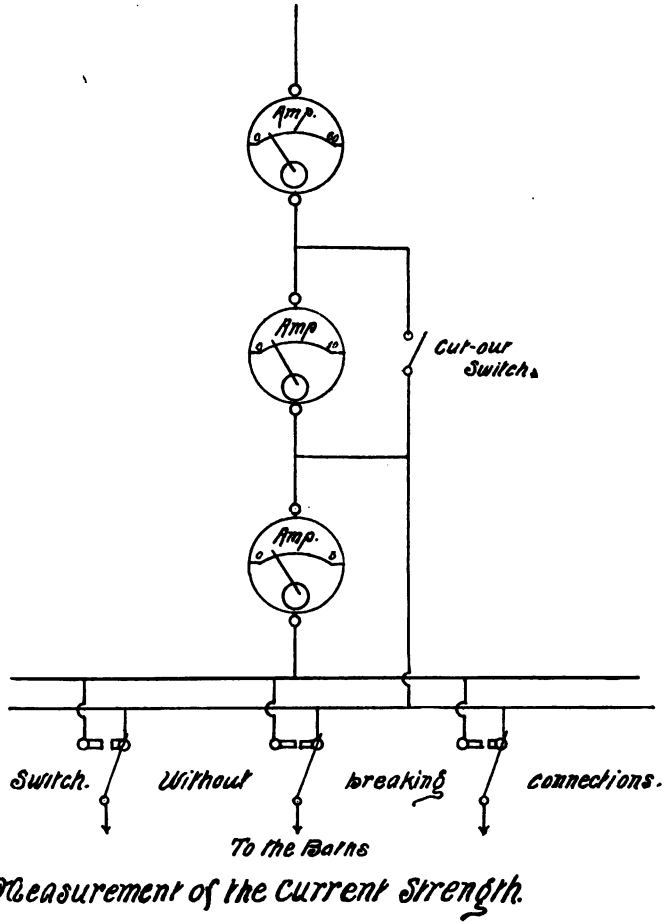


Fig. 32.

After a two years use of my laboratory and continuous observations in other laboratories, I have noted a number of desirable improvements—improvements which for the most part will cheapen the operation, simplify the manipulations and increase the accuracy of the results.

THE ELECTROCHEMICAL LABORATORY OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

BY PROF. H. M. GOODWIN.

During the past year the Institute has equipped a special laboratory for instruction in electrochemistry to meet the demand which the many rapidly growing industries in this branch of applied science have created for men especially trained to undertake the class of problems arising in connection with the development of such industries. As frequent inquiries for a description of the arrangements and equipment of the laboratory have been received during the past winter, it is believed that it may be of some interest and value to those who may be contemplating a similar laboratory equipment to describe briefly the essential features of the arrangements which have been worked out.

The electrochemical laboratory consists of two parts, one devoted to what may be called electrochemical measurements, and to processes requiring currents not greater than about fifteen amperes, and the other to technical work requiring heavy direct or alternating currents up to several thousand amperes. In addition to these two pricipal rooms, six other special rooms equipped for measurements of electrical conductivity. dielectric constants, physico-chemical quantities, and for research, are provided. These contain no essentially novel features in their equipment, and require, therefore, no special description.

The laboratory of electrochemical measurements (30x62 feet), is equipped with desks for twelve students. The general arrangements are indicited in the accompanying plan, Fig. 1, Room I. The most important feature of the equipment in this laboratory is the arrangements of circuits and other conveniences on the desks. These are arranged in three groups of four each with a sink at each end and a large thermostat in the center. Each desk is provided with three faucets, including a Richards suction pump and gas at the sink end. Along the back of each desk is a switchboard, 14 inches high, to which the terminals of the various cir-

cuits are brought. Opposite switchboards are separated by a 4-inch space and bridged over the top by a shelf. This permits ample space at the back of each switchboard for the necessary wiring.

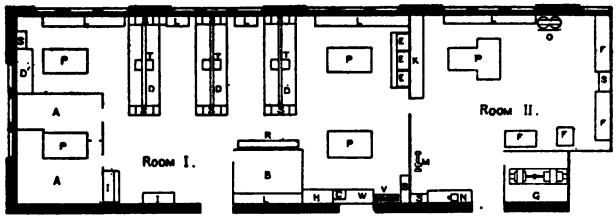
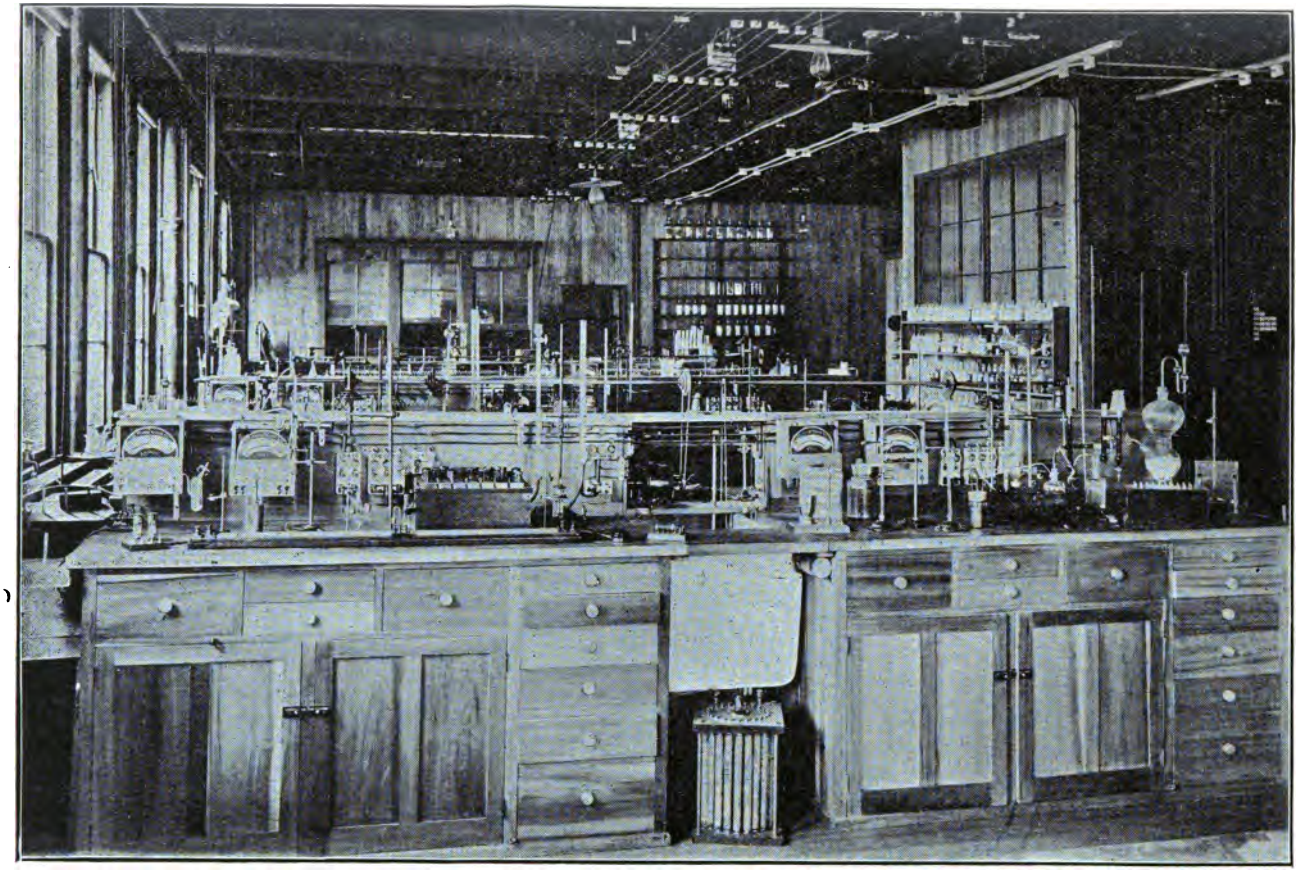


FIG. 33.—LABORATORY OF ELECTROCHEMICAL MEASUREMENTS.

A—Private Office.
B—Balance Room.
C—Hot Closet.
D—Group of four Students' Desks.
D′— Instructor's Private Research Desk.
E—Three Hoods for Electrochemical Analysis.
F—Electric Furnaces.
G—25-kw. Direct-current Motor Generator.
H—Hood.
I—Instrument Case.
K—Set of ten large Storage Batteries and Switchboard.
L—18-inch Shelf.
M—Grinding and Polishing Machine.
N—2-h. p. Power Motor.
O—50-kw. Transformer.
P—Slate-top Masonry Pier.
R—Reagent Shelves.
S—Sink.
T—Thermostat.
V—Steam Evaporating Cups.
W—Special Still for Conductivity Water.

The circuits provided are four in number, 110 volts, 12½ volts, 25 volts, and 2 volts, respectively. The first is wired from one side of the general 220-volt direct-current power circuit of the building; the second and third constitute a three-wire system from a special motor generator located at G, Fig. 33; the 2-volt circuit is connected to a large storage cell, four of which, one for each desk are set up between the desks and under the thermostat. The method of wiring is shown in Fig. 36.

The battery circuits are brought up back of the switchboards as indicated by the dotted lines B. The three-wire 12½ and 25-volt circuit is wired along the top of the switchboard on one side of the desks, and tapped off across to the opposite side as indicated. The three-wire 110-volt and 220-volt circuit is run in a similar manner along the top of the opposite switchboard, and 110 volts tapped off at each desk and across to the proper cut-out on the opposite desk. The circuits are brought out to General Elec-



LIBRARY OF THE UNIVERSITY OF CALIFORNIA

FIG. 34.—GENERAL VIEW OF LABORATORY, LOOKING NORTH, SHOWING ELECTROCHEMICAL EQUIPMENT PROVIDED WITH EACH DESK.

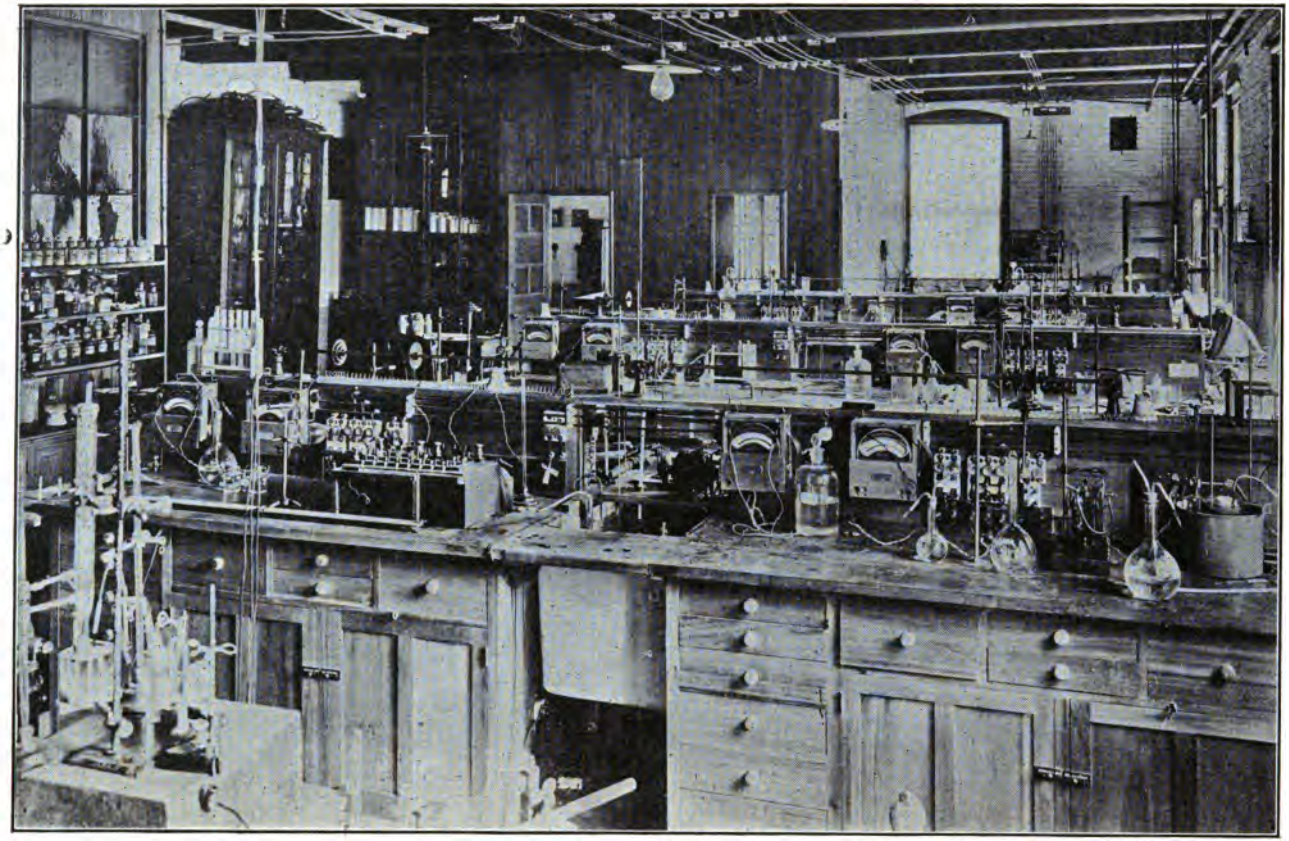


FIG. 35.—GENERAL VIEW OF LABORATORY, LOOKING SOUTH, SHOWING ARRANGEMENT OF DESK CIRCUITS, ETC.

tric porcelain combination switch and cut-outs, connected in turn

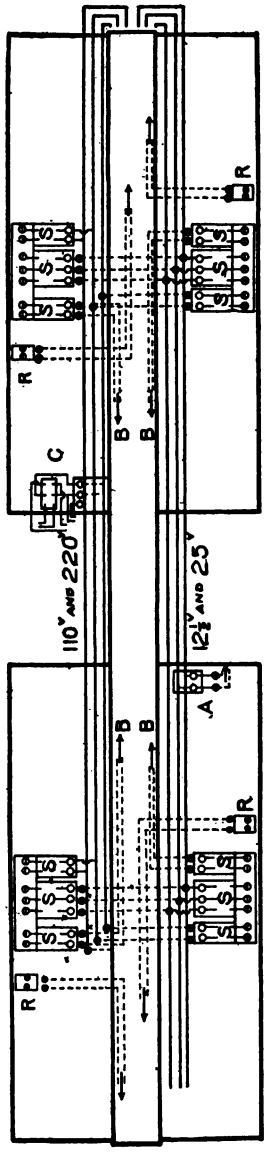


FIG. 36.—DIAGRAM OF WIRING OF DESK CIRCUITS.

A—12½-volt cut-out for charging accumulators for the desks.
B—2-volt circuit to accumulators.
C—Cut-out to circuits leading to 1/12-hp. motor and to heating coils in thermostat.
R—Terminals for rheostat.
S—General Electric combination switch and cut-out.

to large double binding posts mounted on fiber. Each circuit is

fused in general for 10 amperes. Currents of this magnitude may be taken from any circuit without affecting adjacent circuits. The fuse plugs in each circuit may be replaced by lamps of different resistances, a set of which permits a convenient and ready adjustment of current within wide limits. For a finer adjustment of current a large rheostat on the floor at the end of each desk, wired to terminals R, on the switchboard, is provided. For a still finer adjustment of resistance, such as is required in tapping off potentials in determining decomposition voltages, a German silver wire, or coil with sliding contact is stretched between binding posts along the top of the switchboard. The electrical accessories of the desks are completed by portable Weston ammeters and voltmeters. The general arrangement may be seen in Fig. 35, which gives a general view of the laboratory looking south.

The porcelain lined thermostat, 36 x 18 x 20 inches, in the center of each group of four desks, is heated and regulated electrically. The outside is heavily lagged with magnesia to reduce radiation. To bring the temperature quickly up to any desired value, a heating coil of heavy German silver wire is switched onto the 110 volt circuit at C, Fig. 36. A constant temperature is then maintained by an ether regulator which operates a relay mounted at the left of the open space above the thermostat. As the temperature of the bath rises or falls above the desired temperature, the relay opens or closes a 110 volt circuit through a 32-c. p. lamp, the bulb of which is nearly completely immersed in the water of the thermostat. The heat thus generated is more than sufficient to compensate for the loss by radiation and evaporation, and has been found to work most satisfactorily. A small 110-volt 1-12 horse-power motor serves to drive in the thermostat a shaft with paddle wheels for stirring the water, and with a device for rotating bottles for saturating solutions. The motor is also belted up to a shaft which runs the whole length of the shelf at the top of the switchboard. The shaft carries four cones of pulleys, one for each desk, by means of which power is furnished to each student for stirring. A heavy brass rod carrying an adjustable arm with a horizontal cone of pulleys equal in size to those on the shaft, can be screwed, when desired, into a brass plate into the top of the desk.

The equipment of electrochemical apparatus provided with each desk is shown in Fig. 34. It consists of a silver, a copper, a gas and a titration voltameter, transference apparatus, complete conductivity apparatus with a resistance box and a slide wire bridge, a Lippmann electrometer, keys, commutators, a potential box and complete accessories for potential work, a three-scale, 3-volt, 15-volt, and 150-volt Weston voltmeter, and a Weston milli-voltmeter, with 15-ampere auxiliary shunt for use as ammeter. The advantage of giving each student a complete outfit at the start is evident; for first, it permits the whole class to work concurrently on the subjects which are being discussed in the lectures; second, it is conducive to great economy of time in the work of the student, and third, it greatly increases the interest and care with

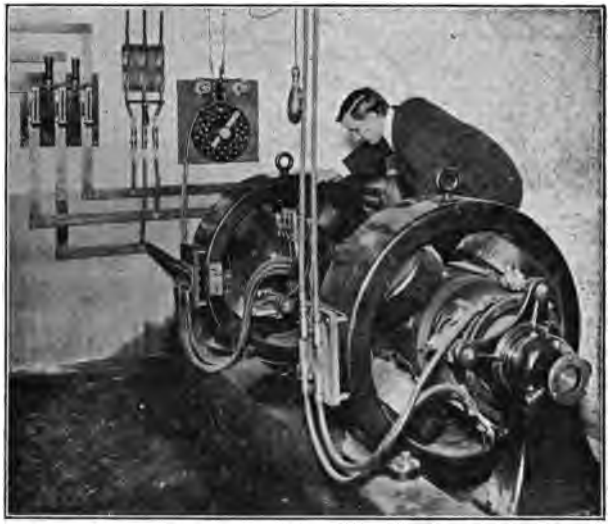


FIG. 37—25-KILOWATT DOUBLE-CURRENT MOTOR-GENERATOR FOR ELECTROLYTIC WORK.

which the student undertakes the calibration and standardization of his instruments, if he feels his own responsibility for them throughout all his later work.

The laboratory is provided with a balance room, a hood, a drying closet, steam cups, distilled water, and a large still of special construction for the redistillation of pure water for conductivity

work. Three hoods of special construction, each equipped with four different circuits of constant voltage connected with the large accumulators, and with means of regulating and varying their temperature, are provided for electrochemical analysis.

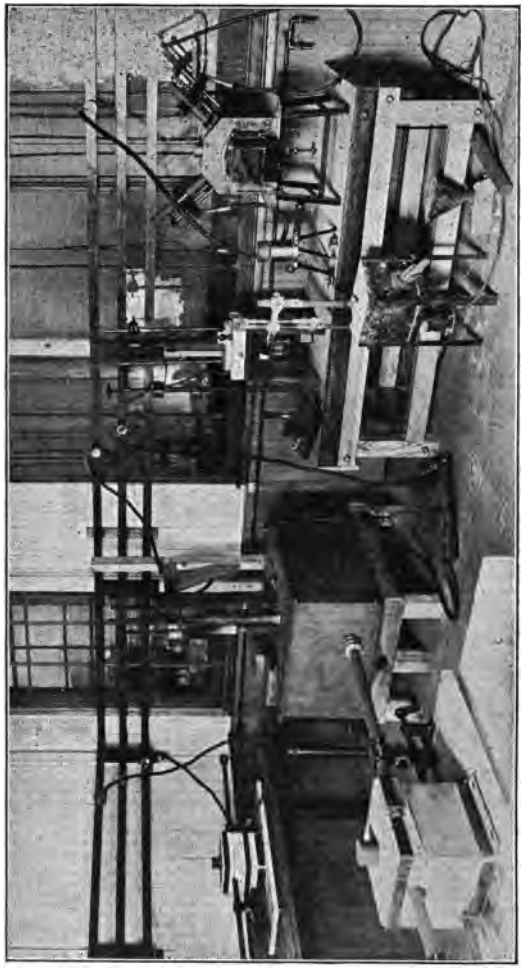


FIG. 38.—ARRANGEMENT OF BUS-BARS AND GROUP OF ELECTRIC FURNACES.

The laboratory for heavy current work, Room II. (30 x 32 feet), is equipped for the purpose of illustrating on a fairly large

scale various electrochemical processes involving the use of both direct and alternating currents, and to provide facilities for research work along these lines.

Direct current is supplied from a Holtzer-Cabot motor generator of 25-kw. capacity, shown in Fig. 37. It is enclosed in a room with glass windows to protect it from dust and acid fumes. The motor is supplied with power from the electrical engineering power plant at 220 volts direct current. The double current generator is directly coupled to the motor and delivers under full load 1000 amperes at 12½ volts at each commutator, which may be connected either in series or parallel as desired. The voltage may be varied at will by varying the resistance of the separately excited fields. The generator may be switched onto the three-wire system leading directly to the switchboard at the front of each desk as already described, or to heavy copper bus-bars 2 inches x ½ inch section and 32 feet in length which extend around two sides of the laboratory, 5 feet above the floor. Connection is made between the electric furnaces, which are arranged along the sides of the room and the bus-bars by means of heavy flexible cables which are easily clamped to the latter by heavy screws. The general arrangement is shown in Fig. 38.

For electrolytic work requiring very constant low voltage, and in particular for work which must proceed continuously over night, such as plating, electro-analysis and electro-depositions in general, a set of ten large chloride accumulators capable of furnishing 150 amperes each are provided. These are each connected to a switchboard by means of which any combination of the cells in series and parallel may be easily effected. Currents from 150 amperes at about 20 volts to 1500 amperes at 2 volts are thus available independent of the motor generator. The batteries are charged in series on the 25-volt circuit from the generator.

For furnace work requiring heat only, and for the purpose of bringing to a state of fusion electrolytes to be subsequently subjected to electrolysis, a 50-kw. transformer of special construction is provided. This is of the core type, and can be used on either a 2200 or 1100 volt circuit at 60 or 125 cycles, by connecting the primary windings in series or parallel. At present it is used on a 1100-volt circuit of 125 cycles. There are 16 independent sec-

ondaries so wound that each can deliver 300 amperes at 10 volts. The terminals of each of these are brought out to a swtchboard where they can be thrown in multiple or series or used in independent combination as desired. The two halves of the switchboard are quite independent, so that 25 kilowatts can be drawn simultaneously from each set of bus-bars at any voltage from 10 to 80 volts in steps of ten volts. By connecting the two halves in series of parallel, currents from 300 to 4800 amperes at pressure from 160 to 10 volts resepctively can be obtained.



FIG. 39.—50 KW. TRANSFORMER SWITCHBOARD AND RESISTANCE FURNACE.

Flexible cables, each capable of carrying 500-700 amperes are used to connect the transformer with furnaces which cannot be built or brought close to the transformer. Fig. 39 shows the transformer connected for a run on a resistance furnace used in an investigation now being carried out on the properties of refactory oxides. The laboratory is provided with all the necessary accessories to the above power equipment in the way of resistances, choke coils, and direct and alternating current measuring instruments for the measurement of current, voltage and power. The calibration of these instruments and of the student's own desk instruments form a part of the regular work which each student performs in the electrical standardizing laboratory. For measuring high temperatures, the laboratory is well provided with

thermo-electric pyrometers. The calibration of these instruments forms a part of the regular work in the laboratory of heat measurements.

The laboratory is equipped with six different types of furnaces, including the Moissan and Borchers type, platinum and graphite resistance furnaces, and a large furnace especially constructed for aluminium reduction. As many furnaces have to be built up for each run, special tables have been designed for this purpose. These contain no wood in their construction except the supports. The tops are concrete arches supported at the sides by iron I-beams. A layer of fire bricks is placed in sand on the cement, and on this foundation the furnaces are built. No danger from fire has been experienced thus far with tables of this construction.

Finally should be mentioned the typical electro-plating plant with tanks of various size up to 30 gallons capacity for illustrating nickel, copper, silver, gold and brass plating. This includes, of course, the necessary grinding, polishing and finishing accessories.

In concluding the above description of the laboratory which has been equipped to provide special facilities for instruction in electrochemistry, it may not be out of place to indicate the general plan of the course in electrochemistry as given at the Institute. The present four years' course was established by the faculty five years ago, and is given under the direction of the department of physics, that department having inaugurated special instruction in electrochemistry as early as 1894. The chief features of this course are very thorough training in theoretical and applied electricity and chemistry, together with as much of the subjects of mechanical engineering and metallurgy as can be included in a course of four years' duration.

The work of the first year is common with that of all other engineering courses, and includes mathematics through analytic geometry, mechanical drawing and descriptive geometry, chemistry, language and general culture studies. The latter are continued in all courses, at the Institute throughout the first three years. Specification begins in the second year in chemistry and electricity. The former consists of qualitative and quantitative

analysis throughout the second year and first half of the third year, followed by organic chemistry, gas analysis and assaying in the second term of the third year. These courses all lead up to a very thorough course in industrial chemistry given throughout the fourth year.

Theoretical chemistry is begun in the second year and is continued to the end of the third year. This forms a very thorough preparation for the theoretical and applied electrochemistry, which constitutes a large part of the professional work of the fourth year.

The electrical studies are also arranged in a progressive sequence. Electricity is treated first in the course on general physics of the second year. Theoretical electricity is then begun in the second term of this year, and is continued through the third and fourth years, the later work being devoted to the subject of periodic currents and their applications to alternating current machinery. Parallel with this theoretical work courses are given in electrical measurements and testing, in electrical engineering and in the electrical engineering laboratory.

In addition to subjects included in the two lines of work described above, a certain number of engineering subjects are required. These include metal work, mechanical engineering, drawing, mechanism, valve gears and thermodynamics, all leading up to a very practical course in the fourth year on general machinery, including engines, pumps, compressors, etc. Non-ferrous metallurgy, and work in the metallurgical laboratory complete the group of subjects included.

In the last term of the course each student devotes a considerable portion of his time to the preparation of a thesis, embodying the results of an experimental research on some electrochemical subject.

Four years is admittedly too short a time to include in a course all subjects which an electrochemist is likely to find useful in the practice of his profession, and a fifth year, or a graduate course which can be arranged to great advantage, is highly recommended to those who find it practicable to devote another year to study before beginning professional work.

LABORATORY OF APPLIED ELECTROCHEMISTRY

University of Wisconsin.

BY PROF. CHARLES F. BURGESS.

The work in applied electrochemistry is under the direction of Prof. C. F. Burgess, assisted by Mr. Carl Hambuechen and Mr. J. G. Zimmerman. The laboratory occupies the second floor of the electrical laboratories, the plan being shown in the accompany-

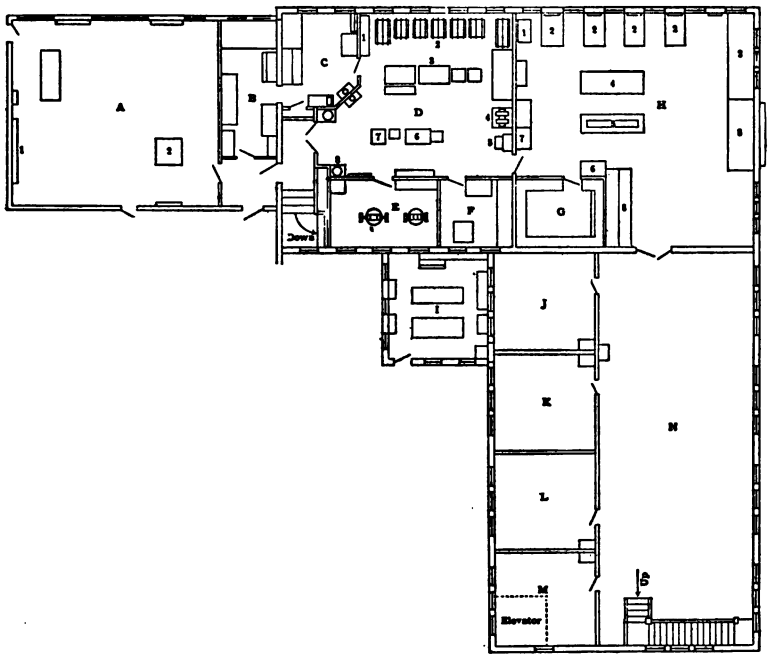


FIG. 40.—APPLIED ELECTROCHEMISTRY LABORATORY.

A. Lecture Room, with projection lantern. B. Workshop. C. Office and Analytical Room. D. Electrodepositing Room. 1. Storage Batteries. 2. Electrolytic Vats. 3. Cleaning Tanks. 4. Motor-Generator. 5. Switchboard. 6. Centrifugal Separator. 7. Rotary Ball Mill. 8. Compressed Air Receiver. E. Grinding and Polishing Room. F. Drying Room. G. Store Room. H. General Electrolytic Laboratory. 1. General Switchboard. 2. Work Tables. 3. Hood. 4. Reagent Stand. 5-6. Instrument Cases. 7. Filter Press. 8. Electrolytic Bench. I. Electric Furnace Room. J. Storage Battery Room. K, L, M. Research Rooms. N. General Laboratory.

ing drawing. The portion of the floor which includes the research rooms is at present in process of construction, and will practically double the space available for electrochemical work.

The present space includes a large plating room, rooms for polishing and grinding, chemical analysis and weighing, work shop, drying room, general laboratory, high-tension room, research laboratories, a storage battery room, and store rooms, one of which is not shown on the plan. On the first floor adjoining the dynamo room is the electric furnace laboratory.

The plating room equipment comprises a motor-generator having a capacity of 300 amperes at a pressure up to 10 volts on the low pressure side; twelve large lead lined, and wood and enamel lined tanks of a capacity of from 30 to 60 gallons capacity, hot water, lye and cleaning tanks. Plating and refining solutions for copper, nickel and zinc are maintained continually, and the other tanks are used for experimental work on various other solutions. A rheostat is connected to each tank, and voltmeters and ampere meters are installed so that by a simple switching arrangement they may be connected to any of the tank terminals. The equipment in the electrodepositing department was obtained chiefly from the Hanson & Van Winkle Co., and is similar to that installed by them in technical plants.

The grinding and polishing room contains two high-speed lathes, driven by an electric motor. By means of the above equipment instruction is given in electroplating, electrotyping, and the refining and recovery of metals.

The equipment of the general laboratory includes eight specially designed switchboards for varying and regulating the current used in small electrolytic experiments, together with a large number of rheostats, electrolytic tanks, stirring devices, instruments for measuring current, e. m. f. and resistance. A considerable proportion of the apparatus has been designed and constructed in the laboratory, and to the valuable assistance of the Mechanism department of the College of Engineering, in charge of Mr. E. H. J. Lorenz, many of the special instruments and devices are due. The equipment also includes balances, filter presses, centrifugal drying machine, a rotary ball mill and other grinding mills, a vacuum drying oven, etc. A system of compressed air furnishes at various outlets around the laboratory air at a pressure of 60 pounds to the square inch.

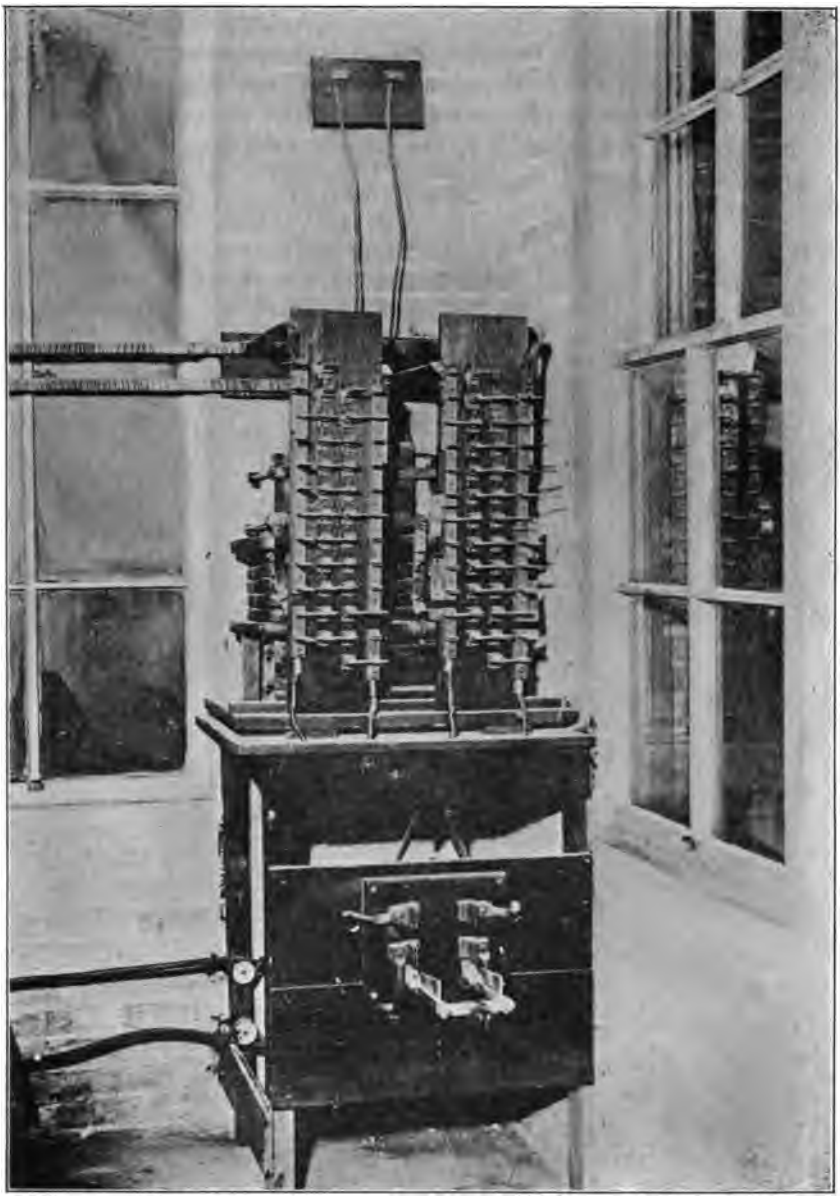


FIG. 41.—20-KW. TRANSFORMER FOR ELECTRIC FURNACES.

Electrical energy is furnished by the dynamo laboratory and by the city lighting and power circuits. Both alternating and direct currents are available, the former in quantities up to several hundred amperes at a pressure of 110 volts, and the latter up to 1000 amperes at the same pressure. By means of a 20-kw. high-tension transformer (Fig. 41) pressures are available up to 60,000 volts.

In the electric furnace room is a switchboard connected to a Bullock direct-current generator, capable of delivering

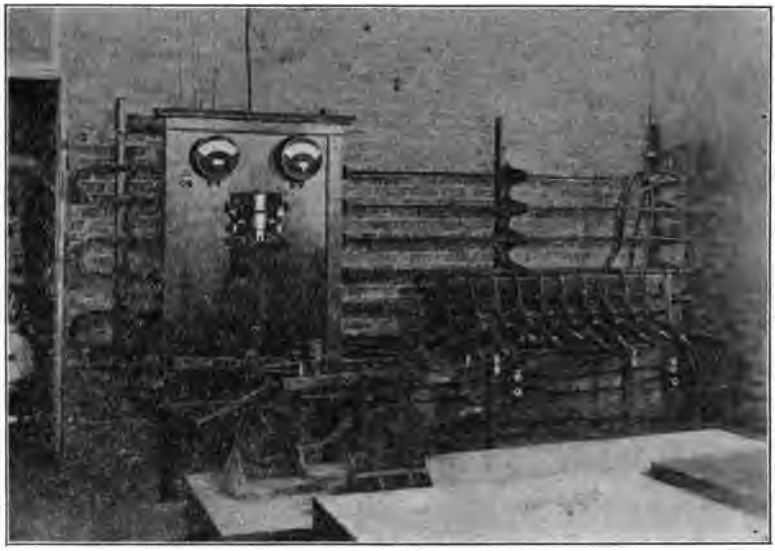


FIG. 42.

1000 amperes at a pressure of 110 volts. This current is regulated and controlled for furnace work by a water-pipe rheostat illustrated in accompanying photograph (Fig. 42). It consists of ten lengths of ¼-inch wrought iron pipe capable of carrying about 250 amperes without excessive heating with no water circulating, and a maximum capacity considerably above 1000 amperes with the water

turned on. The current is regulated in ten steps by opening or closing the switches, which short-circuit the various sections as may be required. A self-acting switch protects the generator and engine from damage by sudden short-circuits. Water is supplied



FIG. 43.

to each of the lengths of pipe through a two-foot length of rubber hose, such material being necessary to prevent short circuits between the consecutive lengths of pipe.

A 10 kw. auxiliary rheostat made by the Wirt Electric Co., of Philadelphia, consisting of cast-iron strips supported on an iron

frame and mounted on rollers serves for handling currents below 150 amperes.

Alternating current for high temperature work is obtained from alternators in the electrical laboratory and from the city power circuit and is at present available in quantities up to 40 kw., although a 200 kw. alternator is to be installed, and in operation within a few months. For adapting the alternating pressures to the various uses required in furnace work a 20 kw. transformer was especially designed for this purpose and constructed in the laboratory. By means of switching arrangements it may receive its full capacity at pressures ranging from 110 to 220 volts, and the switches which connect the subdivided secondaries in series



FIG. 44.

or parallel pressures from 15 to 200 volts may be delivered to the furnaces. A high-pressure coil, capable of delivering 20 amperes

at 1000 volts is used for operating high resistance electric furnaces where the material under treatment is a high resistance substance such as molten silica.

Various small electric furnaces of the Moissan and Borchers types which have been imported are installed and used for various high temperature small scale experiments. Most of the furnaces used have been, however, constructed in the laboratory, various refractory materials, such as magnesite and silica fire-bricks, magnesia, lime, silica, etc., being employed in such construction.

To adapt the electrode supports to the construction of various types of furnaces necessary for a variety of experimental work, two sets of electrode supports have been designed and constructed, and which has given excellent satisfaction. (Fig. 43). These are capable of holding carbon or graphite rods up to 2 inches in diameter, and have a capacity for handling currents up to 1000 amperes, the terminal blocks being provided with water-cooling pipes. The horizontal type is capable of vertical adjustment by means of a slot and lock-nut and the electrodes may be set at any desired angle through 90°. (Fig. 44). The electrodes are adjustable backward and forward by means of lever arms. The vertical electrode supports are an adaptation in part of the vertical type suggested by Mr. R. S. Hutton, of Owens College, Manchester, England.

The work tables of the furnace room are constructed of wood frames supporting a top of concrete and cement three inches thick. This form of top was adopted to reduce danger from fire, but experience has shown that in an experimental room of this sort the entire absence of wood work is desirable.

For conducting high temperature and electrolytic work various new forms of apparatus and methods have been devised, some of which are referred to in the following paragraphs.

In measuring single electrolytic potentials the well known "calomel" electrode is employed, its e. m. f. being assumed as 0.56 volt, and where convenience and rapidity requires the use of cadmium or other suitable metal, the single values of such are determined in terms of the "calomel" standard.

For measuring small electric potentials with a high degree of accuracy a Leeds potentiometer is available, but for ordinary pur-

poses where a decree of accuracy consistent with unavoidable experimental error is attained, a simpler and much cheaper potentiometer outfit has been designed and constructed in the laboratory which permits an accuracy within one-tenth of one per cent. Two forms of this potentiomoter outfit are used. The apparatus was constructed in the laboratory. It consists of 1000 ohms subdivided into ten 10-ohm coils in series, with nine 100-ohm coils, each of these steps being connected to suitable contact terminals to which radical arms make contact. This is an adaptation of the Ostwald potentiometer, with radial adjustment arms which increase the convenience of working, and in addition there is supplied a 9000-ohm coil, which can be placed in series with the 1000 ohms, increasing the range of measurement ten times. By

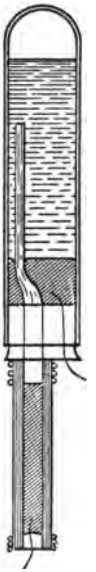


FIG. 45.

means of this outfit, potentials varying from less than 0.001 volt to over 100 volts can be measured with an accuracy of one-tenth of one per cent. It is used for the calibration of ampere meters and voltmeters, the measurement of c. m. f, s., and resistance by the fall of potential method. It has proved especially suited to the determination of resistances of very high value, above 100,000

megohms, such as are encountered in the determination of insulation resistances.

The indicating instrument used in connection with this potentiometer is, for ordinary purposes, a horizontal portable galvanometer or millivoltmeter, but where these cannot be used satisfactorily, a portable capillary electrometer is employed. The form of electrometer which has been found especially adaptable is a modification of the well-known Lippmann instrument, and is illustrated in Fig. 45. It is so arranged that there is no possible ity of spilling the electrolyte. The position of the meniscus is determined by means of a small microscope fitted with a micrometer eye-piece, and the portability of the instrument and the freedom from vibration influences may be judged from the fact that the meniscus may be adjusted upon the scale of the eye-piece and after shipment by express may be found ready for immediate use without readjustment. A portable instrument of this sort was constructed with a sensitiveness of 0.00002 volt, and used for several months in a study of the changes of e. m. f. which are set up by iron under various conditions of strain.

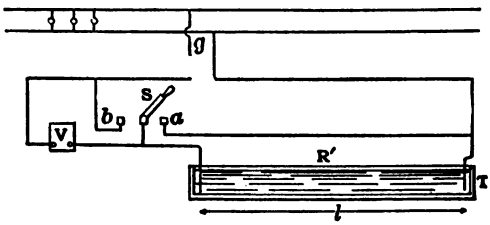


FIG. 46. MEASURING RESISTANCES.

For the measurment of electrolyte resistances the well-known methods are employed. A method which has been found of great convenience, overcoming the various sources of error in a degree sufficient to meet commercial requirements is illustrated in Fig. 46, where an ordinary voltmeter is the only indicating instrument employed. The method of operation consists in placing the electrolytic resistance in a rectangular trough of such length as to furnish between the terminal electrodes a resistance having a suitable proportion to the resistance of the voltmeter. The measurement consists in connecting the cell terminals in series with the volt-

meter to a 100-volt or other convenient source of pressure. By closing the switch S to *a* the voltmeter gives the total pressure E, and upon opening the switch the resistance of the electrolyte is thrown in series with the voltmeter, thereby reducing the reading to the value E′. By applying the following formula the resistance of the electrolyte R′ is derived, R being the resistance of the voltmeter.

$$R' = R\frac{E - E'}{E'}$$

This method is especially applicable for the rapid determination of the resistances of the earth, or any high resistance electrolytic conducting material.

Where is becomes desirable to measure the specific resistance of an electrolyte by simply immersing the measuring apparatus in the solution, as a hydrometer would be used for determining

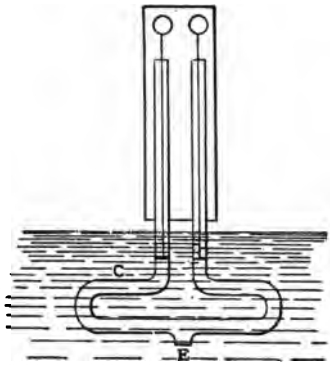


FIG. 47.—MEASURING SPECIFIC RESISTANCE.

the density, a tube containing the electrodes, as illustrated in Fig. 47, is employed. The measurement can be made by means of a voltmeter, as previously described, or by other suitable means.

An important part of the equipment of an electrochemical laboratory consists in rheostats for adjustment of current values. Some rheostats which have been designed and constructed to meet the special requirements of this laboratory are in frequent use. To obtain a small step-by-step adjustment of current for electrolytic work from a 110-volt source of supply,

six wall lamp resistance boards are installed. These permit of range of current from 0.1 ampere to 6 amperes in fifty steps, each board being supplied with an ammeter and voltmeter.

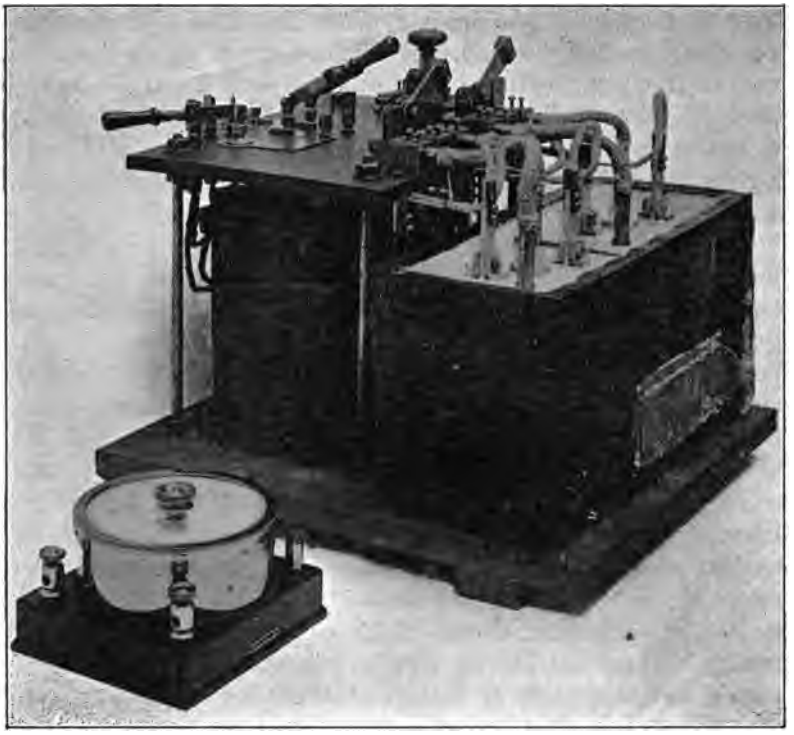


FIG. 48.

Carbon rods mounted on an iron frame and protected by an iron screen constitute a cheap and satisfactory form of rheostat for large volume, low pressure currents. A special form of rheostat for use in the testing of one or two storage cells is also shown. (Fig. 48). It is a combination of switch and rheostat, the side bearing springs being divided into a number of sections faced with carbon blocks about ¼-inch thick. The blade of the switch consists of a metal frame holding strips of carbon, and the two opposite sides of the switch constitute the terminals of the resistance. The resistance

is adjusted by the sliding contact to the exact value desired, this being done by closing the knife of the switch to the desired degree. This form of switch has the advantages of cheapness, gradual adjustment, and large current-carrying capacity.

In an electroplating room one of the difficulties with rheostats commonly used is the corroding of the contacts which therefore require frequent attention. The wall rheostats illustrated in the photograph from the electrolytic depositing room were designed to overcome this difficulty by enclosing the contact points behind a glass cover. These rheostats have now been in use for five years without giving the least trouble from poor contacts.

A high pressure rheostat of low current carrying capacity, and having a sliding contact adjustment, is made by cutting a circular band in a slate or stone slab and filling this with a mixture of graphite, pumice-stone and a binding material, the relative proportion of the material being determined by the degree of resistance and current carrying capacity required. A considerable number of such rheostats are in use and are found to be durable and cheap, and capable of being heated to about 150° C.

The work of the first semester in the applied electrochemistry laboratory consists in performing such experiments as will give an idea of the various methods of making electrolytic measurements of resistance and potentials, of the oxidation and reduction and other electrolytic effects of the current; experiments illustrating the applicability of Faraday's law to the deposition of metals and production of various chemical reactions. The various details connected with the deposition of nickel, copper and zinc and other metals for plating purposes are studied together with the methods of cleaning and preparing the surfaces both before and after receiving the deposits. The effect of current density, temperature, composition, density and circulation of the electrolyte as regards the influence on the character of the metal deposit are illustrated by a set of experiments. Batteries, both primary and secondary, are subjected to tests of efficiency, resistance, polarization, etc.

The work during the second semester deals with the operation and study on a miniature scale of various technical applications of electrolysis and high temperature work. This includes the pro-

duction of hypochlorites, chlorates by the electrolysis of salt solutions; also the production of alkali, chlorine, pigments, metallic sodium, calcium carbide, carborundum, (Fig. 49), silicon, graphite, aluminium, magnesium, and various other materials of a similar kind.

The thesis work and the graduate study in applied electrochem-



FIG. 49.

istry covers largely the study of special problems. While it consists mostly in laboratory investigation it includes also an examination of the literature bearing on the subject, facilities for which are available in the University and State Historical library, one of the most complete libraries in the country, having complete files of most of the important scientific and engineering publications in English, German and French, together with complete sets of the United States, British and Canadian patents.

Among the investigations which are now under way are the following. A study of the electrolytic refining of iron has been in progress for over two years, and with results which indicate that chemically pure iron can be produced as simply and as cheaply as is the case with copper. About one-half ton of this iron has been deposited, chemical analyses of which show no trace of car-

bon, manganese, silicon and other impurities commonly found in iron.

A study of the electrolytic rectification of the alternating current, utilizing the well-known property of aluminium and other

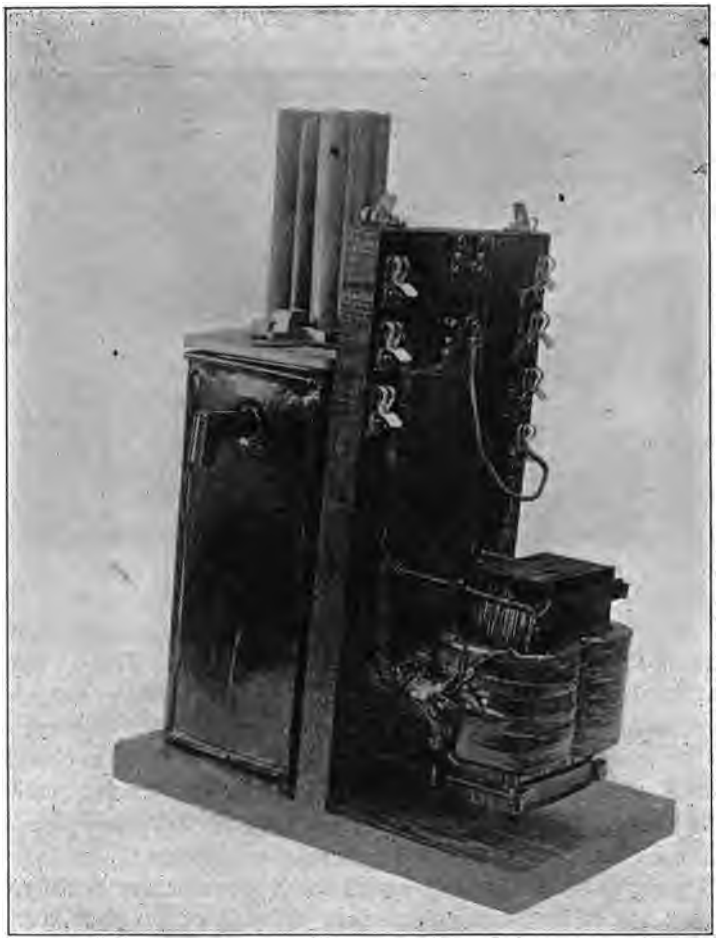


FIG. 50.

metals for this purpose, has resulted in the development of several types of electrolytic rectifiers to fulfill commerical requirements.

Two types, utilizing the fused electrolyte and aqueous solutions, are shown in the illustrations. (Fig. 50).

A study of the distillation and recovery of zinc direct from its sulphide ores has yielded results of value, and the extraction of molybdenum directly from its sulphide without the usual preliminary roasting has been satisfactorily accomplished. The separation and recovery of several of the rare elements from their ores is being studied by electrolytic and electrothermal methods.

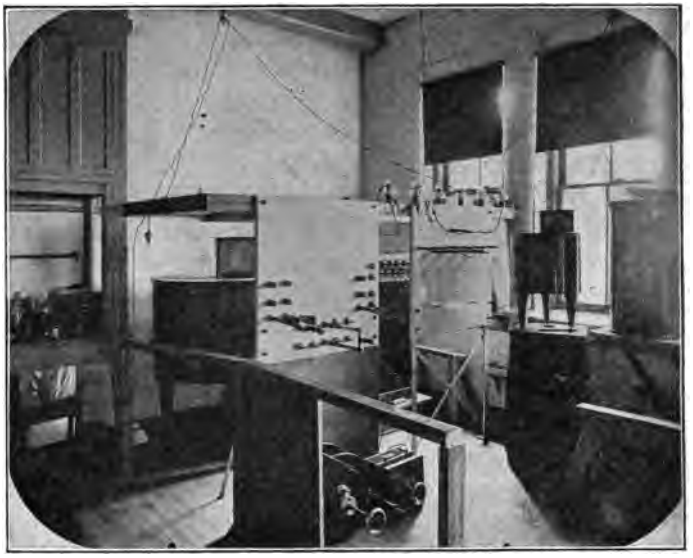


FIG. 51.—50,000 VOLT TRANSFORMER AND SWITCHBOARD.

Investigation of the conductivity of various fused materials is being made for the purpose of determining a suitable material for an electrically heated fused bath for tempering high-speed tool steel, the requirements of which are non-corrosive action on the steel, and electrodes, and maintenance of the electrolyte without decomposition or appreciable volatilization at about 1400° to 1500° C.

Other investigations deal with the fusion of quartz, reduction of tungsten, commercial tests of the Edison storage cell, resistance

and counter electromotive force of copper refining tanks, and the determination of such physical properties of carbon and graphite as relate to the use of these materials for electrode purposes and the construction of electric furnaces.

Among experimental work which has been done within the past few years may be noted the determination of efficiency, cost and commercial considerations relative to the production of hypochlorites, tests on storage batteries of different makes, and upon storage battery plants, and a comparison of most of the dry cells on the market to determine their life, capacity, resistance, and other properties. An extended investigation upon the corrosion of iron showed, among other interesting facts, that iron under strain causes a change in the contact potential of the metal toward an electrolyte, so that a curve showing such changes is similar to the curve of the stress-strain diagram.

An electrolytic stripping process was developed for the removal of copper, brass and silver from iron. It has found extensive application in the bicycle factories of the country as an adjunct to the brazing process.

Zinc plating has been the subject of a large amount of work, and in addition to determining the conditions for the production of the best deposits, a comparison has been made of the protective properties of zinc applied by the electrolytic and by other methods.

A process has also been worked out for the deposition of durable, adherent deposits upon aluminium, as described in the ELECTROCHEMICAL INDUSTRY, March, 1904. Another line of work to which considerable attention has been given is the production of chrome yellow and other pigments.

Various other researches which have produced interesting and valuable results might be noted, but the ones mentioned serve to indicate in general the nature of the work undertaken.

LEHIGH UNIVERSITY

The electro-metallurgical laboratory of the Lehigh University at South Bethlehem, Pennsylvania, is supplied with direct current at 110 volts, from the electrical laboratory, the main conductors having a carrying capacity of 100 amperes. There are also in the laboratory a Gülcher thermopile and three Cox thermopiles, for small current work.

The laboratory has at its disposition a lecture room; a dark room with equipment of microscope, goniometers and polariscopes and drawing table; a room with appliances for crushing and grinding ores, and apparatus for making and polishing thin sections; an instrument room, with cases for instruments not in use and balances,—a coarse balance, analytical balance, and button balance; and with two working laboratory rooms which will be more closely described.

The furnace room, or dry laboratory, is equipped with two wind furnaces, a Pernot gas-furnace for use without blast, a Sefstrom blast-furnace, a gas-fired muffle, a small engine and blower, a Borcher's universal electric furnace, and a Moissan arc furnace; also a gas tank for storing any gas desired, cement floor, apparatus cases, and stone-topped table on brick piers for experiments.

The wet laboratory is equipped with sinks, two hoods with steam baths, hot-air bath, chemical supply cases, and a stone-topped centre-table for analytical work supplied with gas, blast, suction, steam, water and waste-drip. Around the walls are six working places, on oak tables, arranged for electrolytic work, as follows:

Each working space has incandescent lamps of ⅛, ¼,½ and four of 1 ampere, arranged in parallel, so that current may be obtained in steps of ⅛ ampere up to 5 amperes. The measuring instruments are placed in a glass-front box, and consist for each desk of a volt-meter with double scale, showing 0 to 5 or 0 to 50 volts, an ammeter with full scale 1 ampere, divided into fiftieths, and an ammeter with full scale 10 amperes, divided into fifths.

Connecting-wires are led from the instruments to double binding posts on the table, and connections can be thus made without touching or jarring the instruments or opening the instrument cases. Each working space has two large drawers and a stool, and is plentifully supplied with flexible conductors of different lengths with capped ends, thermometers, square and round glass-jars, funnels, beakers, wash bottle, glass electrolytic stands, filter stand, clamps, glass and rubber tubing, etc.

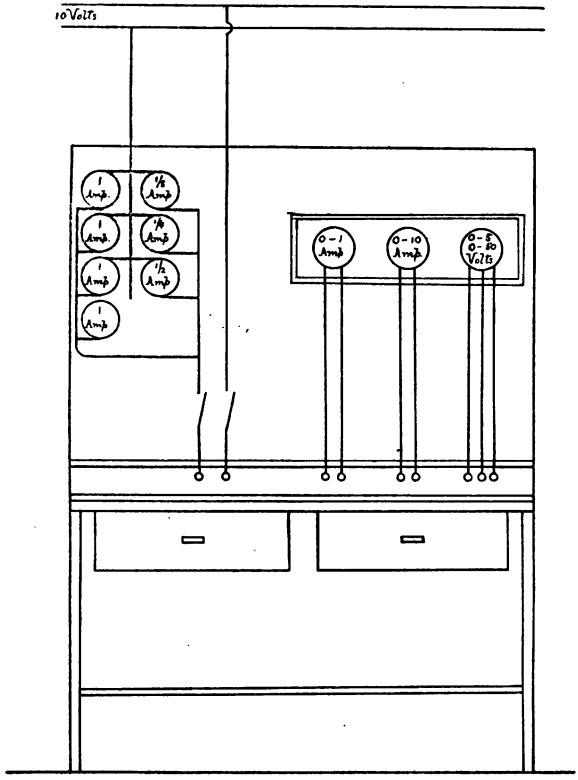


Fig. 52.

The wiring is all insulated aluminium wire, the joints being made by looping the wires and passing a short screw-bolt through the two loops, which on being screwed up flattens the soft wires together and makes a very satisfactory joint, which is afterwards

taped. All short conductors are supplied with permanent brass tips, soldered on, so as to avoid poor connections.

The wiring diagrams is as shown in Fig. 52, which will be easily understood in connection with the description given.

Besides the equipment mentioned, each desk is supplied with reversing switch, and resistance box. There are also in the laboratory a number of extra voltmeters and ammeters of varying capacity, a d'Arsenval galvanometer with reading telescope, cylindrical wire wound rheostat, Ayrton plug shunt, Wheatstone plug resistance bridge, Le Chatelier thermo-electric, Mesuré and Noel, and Wanner pyrometers, calorimeters, etc., etc.

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